Low carbon transition in Northern Ireland: the Green Street Project

Low carbon transition in Northern Ireland

The Green Street Project

Evaluation of a pocket neighbourhood scheme

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Acknowledgments

The cooperation of the 5 families who helped to build, and then moved into Green Street is very gratefully acknowledged. We appreciated their willingness to share their experiences and their hospitality in inviting us into their homes. Green Street is a pseudonym for the neighbourhood in which the evaluation took place, and the names of family members have been changed. We gratefully acknowledge the role of Habitat For Humanity in facilitating this evaluation, and e-Synergy (via Tyrone Timberframes) for the funding that permitted it to be carried out.

"Although design solutions exist for the construction of very low carbon housing, there is considerable concern that many of these solutions are untried and untested within the context of mainstream housing production in the UK. Many schemes do not undergo comprehensive monitoring and evaluation to check whether the approaches chosen have achieved their designed performance targets….The objective of any compliance system should be to ensure that performance standards are met where it matters – on the ground. A few evaluations have demonstrated many of the issues that need to be tackled in order to achieve the goals of zero carbon new housing. Important as the lessons are, it is vital that many more schemes are thoroughly evaluated along similar lines. However, in order to develop this learning process, the cooperation of clients, developers, designers, contractors and the supply chain will be of paramount importance. Equally, the participation of residents is vital. Without the vision and pioneering work of the design, construction and development team, and the forbearance of residents, there will be nothing from which to learn, and no benefits to be gained. Those who strive to achieve high standards, subjecting their attempts to detailed evaluation, require the support and admiration of everyone who seeks a sustainable future". (Bell et al., 2010, p. 8, 12).

Contents

Executive Summary

This evaluation investigates the experience of 5 families that moved into new homes equipped with:

- an innovative building design that aimed to allow households to function without central heating
- SMART electricity meters
- a sophisticated inhouse display unit that provided immediate feedback on electricity being consumed at the present time, as well as a range of comparative data on consumption the previous day, week, month etc.

The aim of the evaluation was to monitor the families before they moved in, and then again after they had experienced their full first winter and summer season. During this time, the evaluation kept track of how the families managed the transition to low carbon living. Energy consumption was tracked fortnightly during this period, and then assessed again during a second winter.

Chapter 1 provides a background for this evaluation, detailing recent legislation related to greenhouse gases and energy efficiency in UK homes . It also provides information on recent findings from similar studies of low carbon homes. Most importantly, it illustrates the extent to which Northern Ireland provides an especially appropriate context for the expansion of low carbon/low income housing.

Chapter 2 presents demographic information on the area in which the low carbon project was situated, illustrating the economic and political context in which the evaluation took place. It also gives details of the design of the houses and early project development.

Chapter 3 provides details of the evaluation design, its procedures and methods of analysis. The advantages of using mixed methods (qualitative and quantitative), and of combining pre- and post-occupancy measures, are discussed.

Chapter 4 contains details of the pre-occupancy evaluation. It illustrates what everyday life was like before the families took possession of their new homes, exploring both their housing

and their social contexts. Data contained in this chapter comprise the baseline against which their transition to low carbon living can be interpreted.

Chapter 5 contains results from the post-occupancy evaluation, which took place after the families had moved in, and follows their experiences for more than a year. We document householder's earliest encounters with their new energy systems, teething problems that arose, and how these were resolved. We also present data on thermal comfort levels and actual electricity consumption based on SMART meter readings. Using their own estimates of energy costs in their previous homes, the families thought they had spent 30% less on domestic energy in their first year at Green Street than they had done in their previous homes.

Compared with the average cost of powering a more conventional home in Northern Ireland at that time, their *actual* consumption costs during their first year was 37% less than people in the average gas-fired home, and 51% less than the average oil-fired home. Confining the comparison to newer homes in Northern Ireland, Green Street households still experienced energy costs which were 20% and 34% less than gas- and oil-fired homes respectively.

The Green Street households were spending an average of less than £1,000 per annum on all of their domestic energy needs, and were experiencing satisfactory levels of thermal comfort. This implies that, at 2011/2 energy prices, households occupying a home of this design could have an income of £10,000 and still not be experiencing fuel poverty.

When followed up after a second winter, the households had reduced their winter energy costs by a further 9%, and achieved improved levels of thermal comfort. This reflected the extent to which they were managing the new system more efficiently.

Chapter 6 concludes that the study, which focused on low income households making their first transition to low carbon living, has demonstrated very positive outcomes. The adaptations and achievements documented were made by households who had no previous interest or experience in managing systems of this kind, which has important implications for social normalisation.

This study is the first report from the UK or Ireland to assess energy consumption in low carbon housing using the acid test of actual consumption data from smart electricity meters. In this sense, it does not rely on occupant assessments or estimated meter readings, but rather on precise readings of fortnightly consumption in kilowatt hours. The evaluation illustrates the significant potential of these low carbon homes, particularly for a region like Northern Ireland where there is so much reliance on oil for domestic heating.

Chapter 1

Aims and context

> "All exemplars provide a learning and training opportunity for the construction industry and the public. For this reason, they are vitally important"
> (Boardman, 2012)

1.1. Background

When this evaluation was commissioned, five families were scheduled to move into new homes in Belfast's Green Street sometime in late spring 2011. The new homes were designed with a revolutionary new building design, which meant that they required no central heating. A patent on the design was pending (and was subsequently granted), and the company building the homes (Tyrone Timberframes Limited) wished to have an independent evaluation made of how the families found living with a new building design. It was a brave move, since evaluations of homes *once completed and occupied* are rare in the building industry, and are even more rare in the case of new and untested designs.

Researchers from the University of Ulster's School of Psychology were appointed to carry out the evaluation, which aimed to monitor the families before they moved in, and for at least one year afterwards. Their experiences in managing the energy system, as well as objective evidence on their energy consumption, form the basis of the evaluation.

1.2. Aims

Broadly speaking, the evaluation aimed to assess the experiences of 5 families before and after their move into Green Street. We hoped to provide:

- detailed baseline information on each family before the move
- insight into the build process and its impacts on families
- a description of their early teething troubles after the move,
- an account of how these were resolved (or not resolved)
- insight into the learning that was embodied in both the successes and disappointments.

1.3. Context: Low carbon housing and the UK climate

Table 1.3 illustrates heating demand in degree days for different parts of the UK & Europe. Degree days is a measure which stipulates a baseline outdoor temperature below which it is assumed that indoor heating will be required to obtain a satisfactory level of heat within a home. The baseline used most often for comparative purposes is 15.5^0C. Hence, if the outdoor temperature on Day 1 is 14.5^0C, then one degree day of heating is required. On Day 2, a temperature of 10.5 requires 5 degree days of indoor heating.

Table1.3. Need for heating (degree days) in 8 Europe countries – lowest to highest degree day demand (Source: Eurostat, 2011)

Country	Heating degree day demand*
Spain	1856
France	2494
Belgium	2882
Netherlands	2905
Ireland	2916
United Kingdom	3354
Denmark	3479
Finland	5823

*Annual average 1980-2004

As can be seen, the UK's climate places it closest to Denmark in terms of the extent to which domestic heating is needed to maintain reasonable indoor temperatures. The UK demand for heating is also widely spread across the year. For example, one-third of Great Britain's heating fuel consumption occurs during spring and summer (Smith & Bolton, 2011). This makes the climate even more suitable for low carbon housing since what is required is most often a consistent relatively low level of heating all through the year, rather than periods of intense need as might be found in Denmark and Finland.

In summary, the climatic conditions of the UK mean:

- energy efficiency is not *absolutely* essential for survival, though close to that threshold

- there is a high demand for heating within the housing stock
- demand is low-level but spread across most of the year

Homes that can readily maintain a steady temperature without the need to cater for extremes are, therefore, especially appropriate for the UK's climate.

1.4. Low carbon housing and Northern Ireland's climate

Being a long and thin island that extends over many degrees latitude, geographic areas of the UK also show wide variation in heating demand. As can be seen on Table 1.4, heating degree days range from 2,144 degree days per annum in London to 3,183 degree days in North Scotland. Northern Ireland requires 83% of the degree days needed in the coldest area (North Scotland), making the region colder than most, and more likely to expend above-average amounts of carbon on domestic heating.

Table 1.4. Need for heating in regions of the UK 1961-1990 – lowest to highest degree day demand (Source: UK Met Office 2009).

Administrative region	Annual heating degree days
London	2144
South West England	2304
South East England	2336
East of England	2401
West Midlands	2527
East Midlands	2550
Wales	2593
Northern Ireland	2633
North West England	2690
Yorkshire & The Humber	2717
West Scotland	2891
North East England	2933
East Scotland	3181
North Scotland	3183

More detail of temperatures in Northern Ireland is contained in Table 1.4.1. Heating demand in Northern Ireland is spread over all 12 months of the year. Even in the warmer months of July to September 2014, there was a total heating demand averaging 157 degree days.

Table 1.4.1. Heating degree days by month for Northern Ireland (2013)

Month	Heating degree days	20-year average
Jan	316	329
Feb	308	287
Mar	372	281
Apr	279	212
May	198	148
Jun	104	81
Jul	34	46
Aug	43	45
Sep	80	77
Oct	111	153
Nov	253	241
Dec	260	325
Annual	**2358***	**2225**

Source: VESMA, 2014 *The annual total for Northern Ireland differs from that shown in Table 1.4, reflecting the number and location of observation points used within the region by different databases, as well as the method of combining the results for each observation point (e.g. area weighting, population weighting or non-weighting)

Hence, the regional climate of Northern Ireland means that heating may be required throughout most of the year; based on the 20-year average data, half of the year (November to April) has a very substantial heating demand i.e. exceeding 200 degree days each month. Such prolonged periods of need mean that houses designed to capture and retain heat will be even more cost-effective in areas of Northern Ireland than they are likely to be in many other parts of Europe or the UK.

1.5. Low carbon housing and fuel poverty

Households are categorised as being in fuel poverty if they need to spend more than 10% of their income on maintaining a healthy standard of warmth and thermal comfort in their homes (Boardman, 2012). One of the principle means for tackling fuel poverty lies in improving the energy efficiency of housing stock. This means that low carbon housing becomes part of the toolbox for tackling fuel poverty as well as playing a central role in climate change mitigation.

Fuel poverty is caused by three factors: low income, expensive fuels, and energy inefficient homes. There are certain conditions under which low carbon housing schemes can be *particularly* effective as a means of tackling fuel poverty. One such circumstance is when homes are relatively energy efficient, but where the cost of fuels is particularly high relative to incomes; methods which allow households fitting this profile to reduce what they spend on heating fuels is a more effective means of reducing their risk of fuel poverty than is raising their income or further insulating their homes (Liddell et al, 2011). These are precisely the conditions that pertain in Northern Ireland. A worked example in the next section illustrates this point. It is based on the economic conditions that prevailed around the time that the Green Street homes were being built.

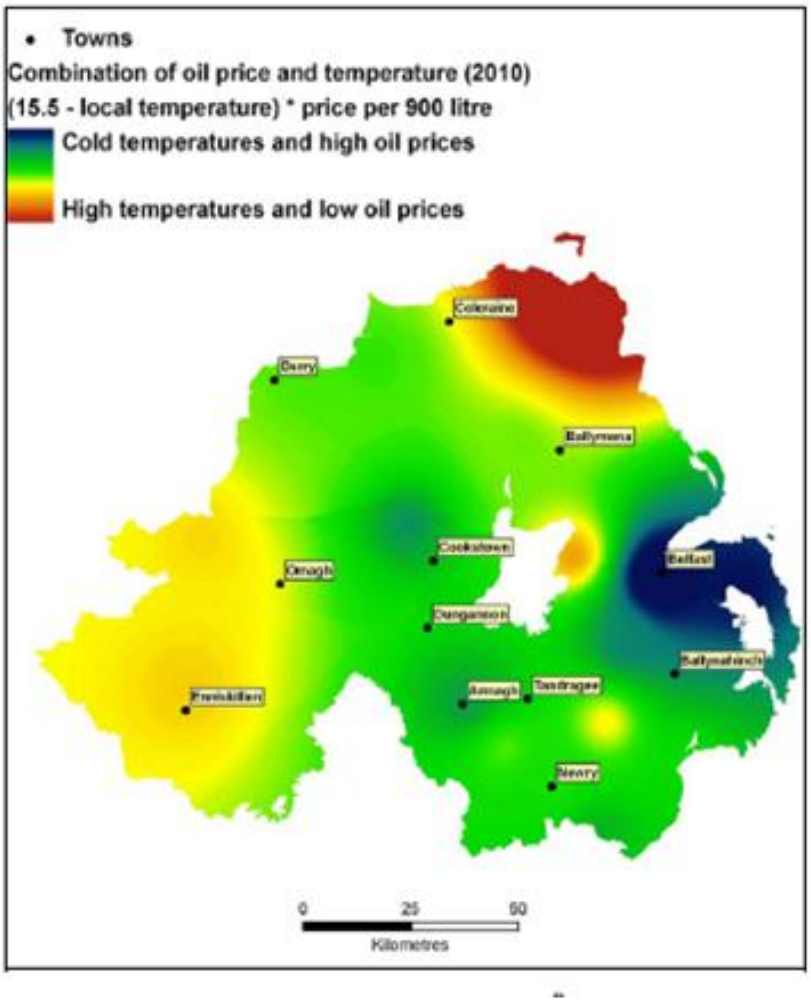
1.6. Fuel poverty in Northern Ireland

- in 2010, an average household in Northern Ireland spent £25.70 a week on domestic fuels (more than the spend of households in other parts of the UK)
- this spend came from an average weekly income of £435.99 (less than the average income of other parts of the UK). This represents 5.9% of income on domestic fuels for Northern Ireland
- if £30 a week were added to their income through increased wages or benefit maximization, they would spend 5.5% of income on domestic fuels, a reduction of only 0.4%
- if, instead they were able to reduce their weekly expenditure on domestic fuels by as little as £5.00 this is a ten times greater reduction (5%) in their weekly expenditure on domestic fuels.

In other words, any measures which reduce energy expenditure rather than increase income will have a substantially greater effect on fuel poverty prevalence, by virtue of the improvement being added to the smaller part of the energy: expenditure ratio. This makes particularly valuable those options for reducing energy expenditure that could stem from finding ways of cutting the cost of space heating and hot water in a home.

Furthermore, Belfast is a particularly appropriate area in which to expand low carbon housing, since the combination of temperatures, energy inefficient housing, and inflated oil prices have made the region particularly vulnerable to fuel poverty. Figure 1.2 provides an illustration of how the combination of low temperatures and high energy prices yielded particularly high fuel poverty vulnerability levels in Belfast at the time the Green Street homes were being built.

Figure 1.2. Mean local temperatures and average prices of oil, 2010 Northern Ireland (Source: Liddell et al., 2011)



These local illustrations of vulnerability can be set in a wider context by comparing them with levels of vulnerability in other parts of the UK. For more than a decade, fuel poverty rates in Northern Ireland have been higher than in any other part of the UK (see Table 1.6); they are among the highest in the industrialised world (Liddell et al., 2011).

Table 1.6. Fuel Poverty in UK by region - % estimated to be in fuel poverty (Source: DECC, 2014).

	NI	Scotland	England	Wales
2001	27	*	7	
2003		13	6	
2004	23	15	6	11
2005		18	7	
2006	34	24	12	
2008		27	16	26
2009	44	33	18	
2011	42	25	15	29

*No data available where cells are empty

Given a prevalence of fuel poverty which has stood consistently around twice that of other regions of the UK, schemes which can bear down on the amount households need to spend on heating and hot water, particularly if they reduce the cost of energy bills in the way low carbon housing can, are of particular value here.

1.7. Low carbon housing and people

The potential of alternative energy systems to deliver in terms of carbon reduction, technical excellence and reliable performance are now beyond dispute, but their performance in the real world is still being tested, and requires extensive collaboration between scientific/technical experts and people who live in the homes that they design. Understanding and valuing the

importance of the "expertise of residents" is the essential but still largely missing link in the wider roll-out of low income/ low carbon homes.

The term "passive house" is often used to describe homes which can be powered with little or no unsustainable energy resources. It is an apt phrase. These homes often rely on "intelligent" automated controls, but it remains questionable as to whether these sophisticated elements can be cost-effectively rolled out across mass low-income housing. For the time being, low income/low carbon homes will not yield carbon savings on their own; they will require regular human intervention, vigilance, monitoring, and adjustment. The homes really are passive, which means the inhabitants sometimes need to be very active indeed when it comes to ensuring that these systems deliver thermal comfort for them.

This is particularly so in climates where one day is seldom the same as the previous one (as in Northern Ireland); here, the success of a low carbon home relies on residents being committed to managing their energy system on a daily basis rather than a seasonal basis.

Supporting the residents of low carbon homes is often referred to as "soft measures" i.e. measures which encourage compliance by the end users of new energy systems. Broer and Titheridge (2010) describe the gains that can be made by involving residents in the construction of their homes, particularly when these are innovative developments. However, specialists at Zero Carbon Hub (2010) believe that there is polarisation between the views of developers and consumers regarding zero and low-carbon homes.

Because legislation recommends but does not make mandatory high-end efficient energy specifications, developers are likely to engage in best practice only in circumstances where they deem it suitable for their business in the current times – it is widely acknowledged that "times" are currently austere and favour low risk. On the other hand, consumers will engage in best practice if it is right for their lifestyle and income – these are currently more favourable for a transition to low carbon housing than ever before. Repositioning the low carbon housing debate so that it focuses more on customer perspectives and customer satisfaction could make for a more rapid expansion of low carbon homes, and an even greater opportunity for innovative trials.

Zero Carbon Hub list 10 ways for marketing low or zero carbon housing to the general public:

1. Clarity of vision. Consumers need to see the big picture and a concept which they can understand.
2. Target influencers. These include facilitators supporting consumers, particularly finance providers.
3. Position new homes as normal. New homes have the opportunity to be the better choice – not a choice that is more expensive or more risky than the existing homes market.
4. Integrate sustainable homes across a development. Avoid segregating low and zero carbon homes on a development, which risks creating a perception that these properties (and those who live in them) are somehow different to mainstream.
5. Avoid radical changes. Consumers respond more favourably to small incremental changes.
6. Build all aspects of a more saleable product. The product must be an economically sound option for supply chain partnerships.
7. Simplify financing.
8. Market these homes, instead of simply trying to sell them.
9. Identify a trusted consumer advisory system. This would provide unbiased and easy to access information.
10. Provide messages that resonate with the consumer. Consumers respond to realistic examples. Focus on marketing examples that seem "like us", rather than flagship exemplar projects which are seen as unattainable.

This evaluation allows an opportunity to explore the extent to which Green Street delivered on each of these recommendations.

Chapter 2
Green Street

"High-performance homes are available when money is not an object. The question is how high performance can be adapted so that it is available in the rest of the housing market, where price is of utmost importance. Changes are needed that make high performance in homes easier to achieve and more affordable... High performance buildings should be inherently more valuable to consumers than conventional homes, because they are designed to improve over time, focus on user needs and become cheaper to operate than conventional buildings. Current methods assessing pricing rarely recognise this. It is, therefore, vital that studies of this sort become more common... Programs that enable home-owner participation without their becoming energy or finance experts, and that will show home owners why moving towards high performance is in their financial interest, are especially important...Encouraging early high-performance adopters will create models for others and accelerate the time taken for widespread public demand for high-performance homes." (Turner & Vaughan, 2010).

2.1. The history of Green Street

The Green Street homes are situated in an area of East Belfast. The first homes in the street were built in 1894 and housed industrial workers employed by the surrounding fabric mills, shipyards and ropeworks (EBHS, 2011). The first homes were made of brick with slate roofs, and cost around £227.00 (Values Office, 1900). The area has been described by many historians and scholars as being a particularly close community with a strong identity, and this remains so today (Byrne, 2005). As a city, Belfast has a long history of political violence based on religious and political differences. Green

Street is commonly regarded as a flashpoint area (i.e. a place where violence or conflict is more likely to flare up), primarily because the Street is on an urban interface (i.e. a place where Catholic and Protestant families live in close proximity to one another). Since the 1960's there have been repeated phases of so-called "voluntary" redistributions of families, with in- and out-migration occurring at times of greatest unrest. During 1971, for example, 98 families from Green Street and adjoining streets moved home. As was remarked at the time "It is difficult to estimate what started the movement because at one point people of both denominations were leaving, often from the same street".

At one end of Green Street, a 20ft barrier was erected in 2002, known as a peace line or peace wall (see Figure 2.1); it functions to separate the two communities and is used to minimize inter-communal violence (Goldstein, 2012). Such structures have been erected around Belfast since the start of the Northern Ireland "Troubles" in 1969. In many cases they have been temporary structures, but in the case of Green Street the peace wall remains in place (Goldstein, 2012).

Figure 2.1. Green Street peace wall

A number of positive community projects are also in evidence in Green Street, for example a community artwork project (The History Girl) (see Figure 2.1.2).

Figure 2.1.2. Part of the History Girl Mural

At one end of the street is a school. Some of the people who moved into the new Green Street homes went to school there as children, and several of them have lived in the area most of their lives, contributing to the close-knit nature of the community which Green Street is known for. The school is now a community center managed by the East Belfast Community Development Association who plan to use this development to improve the quality of life for people in the area. Community projects, family support initiatives, health services, advice clinics, and training programs were all being planned around the time that the low carbon homes were being built (EBCDA, 2011).

2.2. Demographics of Green Street

Green Street covers 4 Census Output areas (COA's); a COA is a unit of 125 households, defined for the purposes of Census data collection. The street has 185 homes on it, mostly terraced, and all of modest size. Most homes are rented out, with only 25% owner occupation (the average owner-occupier rate in Northern Ireland is more than twice that figure). Figure 2.2. illustrates some typical Green Street homes.

Figure 2.2. Typical Green Street homes

Table 2.2 provides demographic and house quality data for these COA's comparing them with the whole of Belfast, and also with the whole of Northern Ireland.

Table 2.2. Green Street in demographic context (Source: NINIS, 2012)

Indicator	**1**	**2**	**3**	**4**	**Belfast**	**Avg NI**
COA Number 95GG	**040012**	**040015**	**040010**	**040009**	**-**	**-**
Deprivation Index	**247**	**468**	**417**	**574**	**1967**	**2511**
Employment Index	**266**	**718**	**653**	**1531**	**2121**	**2511**
Income Index	**274**	**210**	**238**	**924**	**2009**	**2511**
Crime Index	**885**	**2899**	**3965**	**318**	**1525**	**2511**
Fuel poverty risk score	**32.82**	**32.12**	**31.27**	**27.20**	**29.40**	**30.58**
Warm Homes input	**0.09**	**0.35**	**0.15**	**0.17**	**0.18**	**0.22**
Housing quality score	**18.91**	**19.09**	**18.32**	**20.28**	**21.04**	**23.44**
% Post-2000 homes	**0**	**0**	**0**	**49**	**10.60**	**14.84**
Mean house value	**£62,000**	**£86,000**	**£80,000**	**£71,000**	**£117,000**	**£117,000**

Low scores indicate that a COA experiences greater disadvantage. The 4 COA's clearly consist of low income households with modest housing. In terms of overall deprivation (*deprivation index*) it is evident that all of the Green Street COA's are not only disadvantaged, but are within the top 12% of most disadvantaged COA's in Northern Ireland; a similar pattern can be seen in the *income index*. Employment rates are lower than average, and the area has a very variable rate of crime, with one COA being in the top 10% of NI COA's in terms of reported crime (rank of 318), but another being in the bottom 25%. Given that these crime rates are for COA's which are adjacent to one another, it is likely that there are small pockets of high criminal activity embedded in otherwise largely peaceful segments of the street.

There is an elevated likelihood of fuel poverty in 3 of the 4 COA's (*fuel poverty risk score*), which is exacerbated by the relative lack of Warm Homes input in 3 of the 4 COA's (Warm Homes is Northern Ireland's regional fuel poverty reduction scheme which offers free insulation, heating, and boiler replacement to fuel poor families that are on certain passport benefits). Housing scores indicate that all 4 areas have housing of poorer than average quality, whether the scores are compared with the Belfast average (itself low), or the Northern Ireland average; housing is also old with only one of the COA's having any houses built since 2000. Houses are of modest value, averaging less than 2/3's of the price of the average home in Northern Ireland.

2.3. The Green Street Pocket Neighbourhood of low carbon homes

> "A pocket neighbneighbourorhood is a grouping of smaller residences, think of them as a neighbourhood within a neighbourhood. They are designed to promote a close knit sense of community and neighbourliness with an increased level of contact. The fabric of social health in our society has been fraying, in part because many people lack networks of personal and social support…Pocket neighbourhoods can help mend a web of belonging, care and support. Their protected setting encourages informal interaction among neighbours, laying the ground for caring relationships" (Chapman, in Chapin, 2012).

In a pocket neighbourhood, neighbours have a shared stake in the area they live in (Chapin, 2012). The Green Street residents involved in this Pilot took residence in innovative newly designed homes, living next door to one another and sharing the common experience of building and then living in homes that distinguish them from other residents. In ethos as well as geographic setting, they can be

described as a pocket neighbourhood, with characteristics that separate them from the larger neighbourhood of Green Street. They are, therefore, a small pocket of 5 families living in a larger and equally close-knit setting of nearly 200 other families in the same street.

2.4. Starting the pocket neighbourhood

The Green Street pocket neighbourhood of six low carbon homes was originally promoted by Habitat for Humanity Northern Ireland (HFHNI).

HFHNI was founded in 1994, with an explicit focus on reconciliation and the regeneration of communities that have experienced a generation of political conflict. Almost 100 homes have been built using volunteers from both Catholic and Protestant communities, as well as from a wide range of other ethnic and cultural backgrounds.

HFHNI provides a chance for potential householders to unlock hard to access mortgage finance by offering local families a non-repayable partnership grant as a deposit for their home. Eligible selected families work together with volunteers from across Northern Ireland and the local community, helping themselves by "investing 'sweat equity' - minimum 300 hours of their own labour, to build their homes and those of their neighbours" (HFHNI, 2011).

On a wider scale, HFHNI wishes to ensure that new homes provide families with affordable and healthy homes; through building homes together before they move into them, a sense of neighbourhood, cooperation, and shared identity is fostered. Other low-carbon projects similar to the Green Street Project have been carried out in places like Loudon County, Tennessee where a 5-house development was built and evaluated.

2.5. The low carbon homes

The six homes are three-bedroomed and approximate 100 square meters in size. Fig. 2.5 is an early illustration of the homes.

Figure 2.5. Architect's early illustration of the Green Street low carbon homes

The units were designed by an established Northern Ireland building and design company, Tyrone Timberframes (TTF).

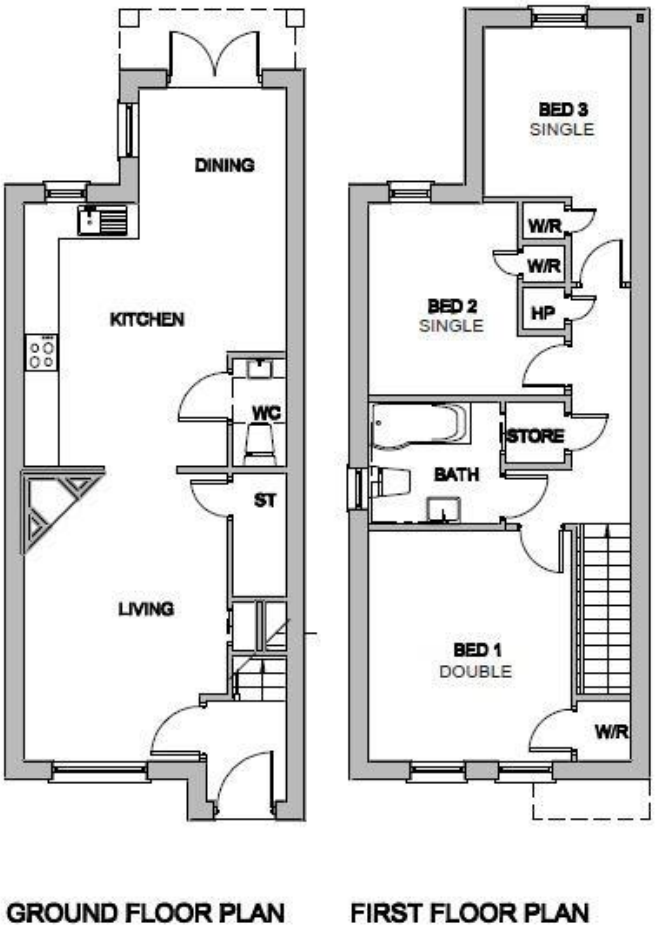
Since 2006, Tyrone Timberframes has specialised in constructing low carbon homes that require no central heating. Their prototype home was built in Donegal 7 years ago, and they have since built homes in areas such as Roscrea, Kilkeel, Helen's Bay and Belfast. The Green Street development was their first pocket neighbourhood scheme.

TTF seek to future-proof homes by making them as energy efficient as possible. The technology is based on research, innovation, and cutting edge design, and is suitable for most self-build markets. Unusually, the energy efficiency requirements of the home are not the driving force behind the home's overall design and appearance. Rather, the EE requirements are led by the client's requirements for a home that is functional and aesthetically pleasing. In other words, the technology can be applied to almost any house and will not impact upon the original design.

Homes designed by TTF aim to avoid the need to central heating altogether. This requires detailed specifications of highly insulated fabric**,** high performance glazing, air-tightness, mechanical ventilation with heat recovery and ultra-low air permeability levels. Whilst these are all expensive to purchase, the costs are offset by having no need for a central heating boiler and its associated plumbing and radiators. Whilst it may cost a little more at the time of building a house of this kind, savings are made throughout the home's lifetime, since heating costs are kept to a minimum.

The purchase price of each home was £90,000, slightly more than the average price of a home in Green Street. They consisted of two floors (see Fig. 2.5.1). An open plan kitchen and dining area at the back link through to a sitting room at the front of the properties. There is a downstairs toilet and sink, and stairs that lead to the first floor. A double bedroom and two single bedrooms are served by a bathroom containing bath, shower and toilet.

Figure 2.5.1. Floor plans of the Green Street properties



2.6. Recruitment into the pocket neighbourhood scheme

Habitat For Humanity Northern Ireland (HFHNI) recruited applicants for the scheme primarily through leaflets that were distributed in local churches. As with all Habitat for Humanity projects of this nature, people who signed up to be part of the scheme did so off plan, and were

subsequently expected to assist in the construction of all of the homes in the development, not simply their own home. Residents were required to spend more than 7 working weeks on site. Along with a large and varying group of local volunteers, they assisted an expert building team, which was in turn monitored by TTF. Volunteers included students on a day or a week of work experience, team-building groups from local businesses, volunteers from local churches, people from other HFH schemes elsewhere in the world, as well as the friends and families of the 5 households who had joined the scheme.

Finance for purchasing the homes was based on a co-ownership model, with Clanmil Housing Association being the main initial stakeholder in properties. Mortgage payments from the residents were around £400 per calendar month, and ownership is based on a shared equity agreement which means that families will own the homes once the mortgage has been paid off.

The families participated in the construction of their homes. They had no previous experience of building a home, or of low carbon living; only one of the families had owned a home before. The levels of support and advice available through the partnership with HFHNI were important factors in helping the families decide to join the scheme. The fact that their low carbon homes had been designed by an experienced building company, who subsequently monitored the build, also minimised the obstacles encountered by most UK households when building a low carbon home. These are most commonly:

- unfamiliarity with emerging methods and technologies (Kyser, 2012)
- sourcing appropriate products and systems
- assessing products and systems
- finding suitable trades people to install them (Turner & Vaughan 2010).

2.7. Design specification of the homes

The walls, roof and first floor of the Green Street homes are primarily wood-based. Whilst they are in many respects a conventional timber frame, they include a variety of thermally efficient high performance materials, often installed in layers (see Fig. 2.7).

Figure 2.7. The Green Street properties under construction

Windows are triple glazed with an inert gas filling and maximum use is made of solar gain. Two solar panels and a supplementary air source heat pump provide homes with hot water all year round. Mechanical ventilation extracts warm, damp air from the kitchen and bathroom areas, recovering up to 85% of the heat it contains, passing this heat into the incoming fresh supply of air. It was hoped that the heat loss from the homes would be such that an additional heat source would only be required for about 3 months of the year. This additional heat would be provided by a small electric- or gas-fired heater or heaters, to be placed in the main living spaces. The heat output from these heaters could be transferred around the house through the use of the mechanical ventilation system. The cost of these supplementary heat sources was estimated by Phoenix Gas to be £120 per annum at the time the homes were being constructed.

The specification used in the building of the Green Street homes did not meet the "passivhaus" space heating benchmark of 15kWh/m^2 pa, although it has the capability to do so with minor modifications. While it does not meet full compliance with the Code For Sustainable Homes, it reaches the Code's highest level (Code 5) in terms of thermal efficiency and energy usage. It can be built for the same cost as a Code 4 building of similar size and build quality, and the homes come with a 10 year NHBC guarantee. To all intents and purposes, provided these homes approximate their design specifications when in use, they comprise some of the most energy efficient houses in Northern Ireland, and certainly the most energy efficient low income homes in the region. In 2011, the Green Street Project won an Action Renewables award for the most Innovative Construction Project.

Table 2.7 presents some of the design criteria for the Green Street homes. U-values are a measure of the flow of heat through a building element such as a wall, floor or ceiling. Broadly speaking they represent the temperature difference between the two sides of a building (e.g. between the exterior surface of walls and the interior surface of walls). The lower the U-value, the better the insulating ability of the building element, and the more energy efficient the building.

Table 2.7. Design Criteria for the Green Street Homes

Element	**Standard**
Walls	U-Value 0.125 W/ m^2K
Roof plane ceiling	U-Value 0.11 W/ m^2K
Roof sloped ceiling	U-Value 0.11 W/ m^2K
Floor	U-Value 0.11 W/ m^2K
Windows	U-Value 1.0 W/ m^2K
Air tightness	<2 $m^3/(m^2h)$ @ 50 Pa
Ventilation	MVHR > 85% heat recovery

By way of comparison, the Elmswell Three Gardens scheme in Suffolk, England, experience U values of 0.25 W/m^2K (Combe et al., 2011), illustrating the superior efficiencies being obtained in the Green Street homes.

2.8. Recruitment of the families into the Evaluation

The present evaluation seeks to document how the families found the experiences of building a low carbon home and then living in one. Their consent for this evaluation to be done was sought during the building process when the University of Ulster team was first appointed to evaluate the project. A first meeting with the 5 Green Street families was held in late 2010. The proposed evaluation process and its purpose were explained to them, and families were provided with a booklet containing copies of the evaluation materials the University intended to use, as well as a timeline of when we proposed to meet with them. The families were asked to take their time in considering whether or not to participate, and they were provided with stamped and addressed envelopes that could be returned to UU if they wished to take part. All 5 families agreed.

At the time, the sixth home was without a designated owner: the original successful applicant had withdrawn from the scheme due to unforeseen circumstances. The house remained the sole property of Clanmil Housing Association, and it was not occupied for several months after the building was completed. The residents were not approached to join the evaluation.

Chapter 3
Methods of evaluation

"The built environment represents a social ecosystem, requiring a systemic approach. It should be investigated by a wide range of multi-disciplinary methodologies and tools, including those from environment-behaviour research. Post-occupation evaluation that uses a number of different approaches overcomes the limitations of individual approaches, and in many instances can help explain the complex interaction of factors when user behavior is related to building performance" (Fontana, 2012).

3.1. Ethical clearance

Ethical approval for the evaluation was sought from the University of Ulster's Research and Governance Filter Committee for Psychology in February 2011 and was approved for this project.

3.2. Design

The evaluation comprised a Pre- and Post-Occupancy Evaluation (PREOE and POSTOE). POSTOE is a very common methodology in evaluations of low carbon transitions; it considers the social and environmental impacts of a building once residents have been living in the building for a sustained period of time.

By also incorporating PREOE i.e. evaluation of occupants *before* they relocated to their new homes, this evaluation hoped to assess:

- Some of the building experiences of the families as their homes neared completion
- Their before-and-after context, comparing their experiences in their new with their previous homes

Combining PREOE and POSTOE allows for a more rounded evaluation of the before-and-after transformations that households experience in a project of this nature; they allow more opportunities

for identifying aspirations and expectations, as well as any changes in residents' energy awareness and lifestyle choices which may be brought about as a result of the transition to low carbon living.

Pre-occupancy Evaluation is rare in studies of this kind, as noted by Gupta and Chandiwala (2010):

"*there is little time within projects to undertake comprehensive pre-intervention monitoring and occupant surveys. The client and the design team are usually more interested in the new improved models for living*."

Post-occupancy Evaluation considers how and whether a new energy system affects factors such as thermal comfort, noise, ease of control, expense, and lifestyle. We were especially keen to assess the use-ability of the homes, since research over the past 10 years has indicated a steady decline in the extent to which residents perceive themselves to be able to control their heating and other energy systems (Combe et al., 2011). This threatens any successful transition to sustainable low carbon housing. Controls which offer use-ability and thoughtful interfaces with residents are found to give superior results in terms of user satisfaction and compliance. Function, location, clarity and responsiveness are all essential ingredients, particularly in houses which have novel energy systems that will be used by residents with little initial interest in energy efficient housing.

In this context, research suggests that between 9% and 30% of households who have new energy systems installed are unable to use them in a manner which permits them to maximize their savings. In particular the visibility of interfaces between the householder and equipment, their cognitive demands (e.g. memory for sequences, understanding of graphs and temperature scales), and the need for dexterity place significant limitations on what can be achieved by many householders (Combe et al., 2011).

3.3. Role of the research team

The research team attempted to adopt a user-friendly approach to evaluation, founded on the principles of Action Research. Action Research focuses on processes rather than outcomes, and gives researchers flexibility to work within the system they are studying. It is well suited to the sort of experiences and narratives that need to be disentangled in pilot schemes of this kind, where little if anything can be predicted beforehand. We avoided as far as possible the principles of detached measurement and observation opting instead for the role of occasional participant observers. As far as possible, we tried to have only one researcher involved with the families; by chance, she also grew up

nearby. She became the evaluation's "face". She was present at all meetings, and carried out all of the interviews and recording sessions. The insights gained in Action Research stem largely from a researcher's willingness to listen and learn, coupled with the mutual respect and personal relationships that are developed along the way. All 5 families were immensely tolerant of our attempts to document what they shared with us.

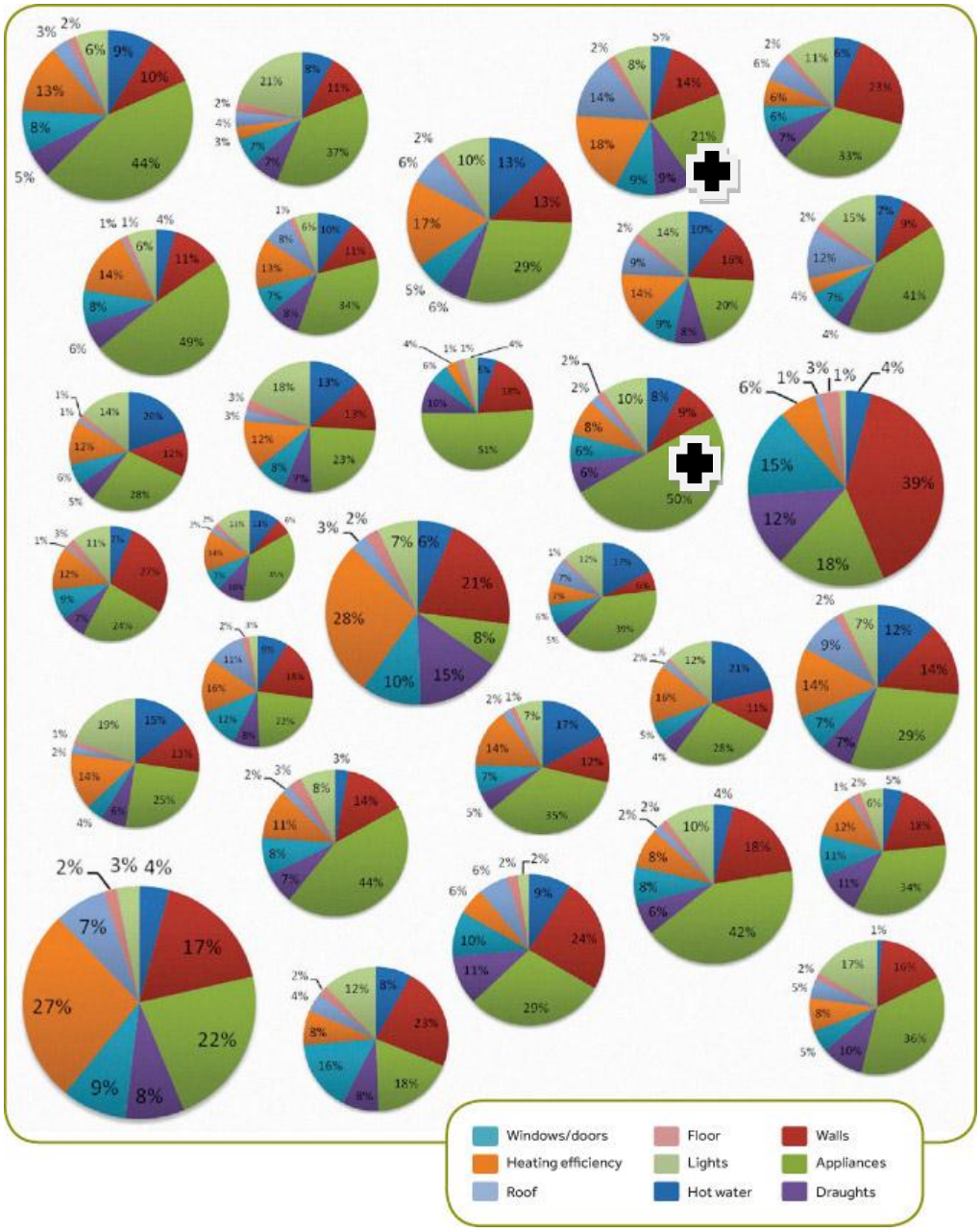
3.4. Units of analysis

The evaluation is mainly based on the collective experiences of all 5 families. For example, no attempt has been made to distinguish between their individual comments or remarks when reporting information from the recordings we made.

However, in terms of energy consumption, we report this for each individual household anonymously. According to the Building Research Establishment (2011), the average UK home consumes 3,300 kWh of electricity per year, although other studies report somewhat higher consumption (e.g. Boardman, 2012: 4,577 kWh). It has long been observed that energy consumption varies considerably from one household to another, even when they are living in houses with similar physical attributes. Consumption depends on who lives in a house, how often people are at home, how active they are, and their lifestyle choices. Consequently, studies vary considerably in terms of their estimates of what constitutes "average" consumption.

This is clearly indicated on Figure 3.4, which illustrates energy consumption patterns in several London homes of similar age and type. The size of each pie indicates how much energy a household consumes – in other words, the large pie in the top left corner consumes almost twice as much energy as the smaller pie immediately to the right of it. The segments indicate how overall consumption divides up by type. The two pies marked with a  show very similar amounts of energy consumed. However one of the homes consumes twice as much through appliances as the other, but also uses half as much energy on heating and hot water as its comparator. The percentage of consumption taken up by heating, when this is compared across all of the households in Fig. 3.4. ranges from 3% to 28%.

Figure 3.4. Energy use in adjacent London homes of similar design (Source: Institute for Sustainability, 2011)



As a consequence of this variability in consumption across similar households in similar dwellings, we assessed the energy consumption of each of the Green Street families separately.

3.5. Instruments and Procedure - Pre-Occupancy Evaluation

The PREOE consisted mainly of an informal question and answer session which took place in the homes of each family. A set of key questions were covered, although participants were free to range across any other topics that they wished to. The questions were:

- When you first heard about the scheme, did it take you long to decide to take part?
- Was anyone in the household more keen than others on the scheme?
- So far, have things turned out as you expected?
- How long have you lived in this house?
- How have you found living here?
- How does it feel to be nearly moving?
- Can you tell me what everyday life is like for you at the moment?
- What will you miss most about living here?
- What are the best thing about being involved with the Project so far?
- What are the worst things about your experiences so far in the new build?
- How do you feel about having a home with no central heating?
- How can HFHNI make the early parts of the scheme better in the future?
- Are there any other things we should note down?

All adult members of the family were invited to participate in the pre-occupancy evaluation, and the conversations were tape recorded for later transcription. They were transcribed verbatim and copies of transcripts were posted to each family for editing and approval. The Pre-Occupancy evaluations were intended to take place shortly before the families moved into their new homes, although events transpired in such a way that their relocation took place several months later.

In addition, households were asked to complete 2 Pre-Occupancy questionnaires, which provided the evaluation with some standardized data on their satisfaction with the home they were living in prior to their move. The first of these was completed by the researcher at the end of the recording session. The second was completed by members of the household on their own and posted to the University thereafter.

It is important to note that the families seemed least comfortable with completing questionnaires when participating in the evaluation. For example, it took some time before most of the second ones were returned to the University, and some never were. Although they were completed anonymously, our in-depth knowledge of the families meant that anonymity was not always something we could reassure families about, and we were concerned that this was potentially breaking trust. Consequently, we did not use questionnaires in the post-occupancy evaluation. We have also drawn very little from the questionnaires in the evaluation reported here, relying only on a few responses to generic questions that cannot be traced to individual households.

Members of the team also attended the official launch of the Green Street pocket neighbourhood, and made a variety of other informal visits to the families by prior arrangement. Notes were kept on each of these contacts, to provide additional background information that might help us interpret their experiences later on.

3.6. Post-Occupancy Evaluation

The POSTOE consisted of a recording session only. A different set of key questions was drawn up, but the same procedure was followed as in the first question and answer session. The questions were:

- It's been almost a year now since you moved into your new home, how do you feel about that?
- Have things turned out as you expected?
- How have you found living here?
- Can you tell me what everyday life is like for you at the minute?
- Do you miss anything from your old home?
- Have you found any difficulties dealing with this new type of system?
- Are you happy with the amount of hot water in the home?
- Do you think that this type of system and living is more cost effective?
- Would you recommend this type of scheme to a friend?
- Has this been a worthwhile experience so far?

At the post-occupancy evaluation, the families were also asked to complete a standard thermal comfort scale (the ASHRAE Scale), which evaluated levels of thermal comfort in their living room,

main bedroom, child's bedroom and bathroom. The families agreed ratings on a 7-point scale from "too cold" to "too hot ", and completed the scale for comfort levels experienced in winter and summer separately.

3.7. Energy consumption

The Green Street homes relied almost exclusively on electricity for their domestic energy needs. At the time they agreed to participate in the evaluation, the University was also managing the first SMART Meter Trial in Northern Ireland. The families were asked if they wished to join this Trial, following an informal briefing session on what SMART meters are and how they can be operated. All agreed to do so.

The SMART meters were installed in November 2011 and were accompanied by a portable in-house display (see Fig. 3.7). The meters have provided information on 52 weeks of electricity consumption for 4 of the households; regrettably one of the meters functioned only intermittently (despite being replaced) and could not be used for data analysis purposes.

Figure 3.7. The SMART meter's in-house display

In addition, 2 of the 5 homes (at the gable ends) had a small gas fire installed in the corner of their living room; in the remaining 3 homes, the fires used electricity.

Chapter 4

Pre-occupancy evaluation

4.1. The families.

Jack and Marian

At the time they joined the Green Street project, Jack and Marian were living in a rented semi-detached home that had been built in the 1950's. They are in their early fifties, and heard about the Green Street scheme through their local church. They had been contemplating the prospects of spending the rest of their lives in rented accommodation, and for that reason the scheme came along at a particularly opportune moment. Jack remarked:

"The relief…that we would be a home owner and the house was going to be paid off when I retired and that was our future – in a lovely new home".

Jack and Marian spent very little time contemplating whether to participate in the Green Street scheme, embarking on fact-finding the day after the church service. That being said, the home they were renting at the time was one they had few if any complaints about. In particular, the sense of a neighbourhood emerged as a strong theme from their transcript, and this was something they anticipated being a feature of their new pocket neighbourhood too:

"Great neighbours, honestly that to me makes it all, and that is what is exciting about Green Street, we have worked with our neighbours, we have helped build their house and they have helped build ours and there is a rapport there."

However, for both of them there was an advantage of living in Green Street, since they were both originally from the area; they held a fondness and attachment for Green Street, it was part of who they were, and in moving there they felt they knew what to expect.

Graham and Sally

Graham and Sally are a couple with two young children. Their rented accommodation before the move consisted of a pre-1950's terraced house, which was situated very close to their new Green Street home. Sally had already lived in the area for most of her life and had many relatives living

nearby. The location of the new homes was, therefore, as essential to Graham and Sally as it was to Jack and Marian.

"I have always lived around here; this has always been where I have come from, round this area, there is no way I would move away from this area"

Nevertheless, Graham and Sally took some time deciding whether they would like to move. They were expecting their second child around the application time, and at first gave moving home little thought. Over time, however, the prospect of a bigger home for their growing family became more appealing:

"We didn't really have it in mind, but when we thought about it, this is only a two bedroom house and that's a three bedroom, so we just thought we would try for it and see what happens"

The Green Street homes seemed suitable for all of these reasons, giving them more bedrooms in a familiar area and an opportunity to own a home.

"No well it's handy, it's good help for the kids and all"

Sally's "mum is close by, and it's near my work, and we are happy enough".

"We wouldn't have got a mortgage, a full mortgage so it gives us a chance, something to start off with and then we can buy as we go on. The extra room for the kids too"

Having an existing sense of belonging and an opportunity to sustain the traditional family, community and neighbourhood cohesion that exists, were important factors for both these two families.

<u>Rob and Susan</u>

Rob and Susan rented a pre-1950's terraced house at the time they joined the Green Street scheme. The house had been rented, and was old, only partly double-glazed, and expensive to heat, although the quality of the neighbours and the neighbourhood compensated for these issues.

"Awk, the neighbourhood's good and I like my neighbours, the house is just real old"

Before they became aware of the HFHNI scheme, neither Rob nor Susan had anticipated being able to purchase their own home in the foreseeable future.

"Just because I was in a rented house and I was paying rent and I could not have afforded to pay a deposit as well as paying rent."

The couple was very glad to be taking part in the scheme as this meant that they were able to purchase a house at an affordable price, something they could not have done before.

"This is a good house for the price, compared to what I could have bought or I couldn't have been able to afford to buy, so the deposit for this was good"

The family were looking forward to Green Street becoming their new home and hopefully spending a bit less on domestic costs.

At the time it was ok, like I said, it was just basic, you were just getting by like, there was no heart it in it, it wasn't my house. Every month you were paying rent and lining someone else's pockets. It's good to get out of it as well; it was a house not a home.

Rosemary

Rosemary and her family were not born in Northern Ireland. Rosemary and her 3 daughters rented a house on the outskirts of Belfast for two years before moving to Green Street. It was a large semi-detached house which had been built only a few years ago. Living 11 miles from the city centre was proving to be challenging for the whole family, since Rosemary works in Belfast, and her daughters all go to school in the city.

"All our doctors, dentists, everything is in Belfast. I don't know why we moved here to rent".

They heard about the project very close to the closing date for applications and signed up for it immediately. However, they changed their minds when another house became available elsewhere, and then returned to the Green Street Project when that sale fell through.

For this family in particular, there was an expectation that their new home would provide them with significant savings – not only in energy and hot water (which they consumed a great deal of in

their rented 3-bathroomed home), but also in transport costs. The family anticipated having much more leisure time in Green Street, since travel on public transport consumed a great deal of their day. They perceived themselves to be doing little more than using the rented house to sleep in.

Unlike most of the other families, Rosemary and her daughters had not enjoyed good relations with their neighbours in their rental house , and this too meant that they had expectations of a better life ahead:

"I won't miss any of the outside or the people that live here as it really annoys me they are not very nice people. I think everything will change for good".

Karl and Irene

Karl and Irene had rented a fairly modern East Belfast apartment with their young son for almost two years before the Green Street project was advertised. They were both concerned at first about moving to an unfamiliar area, as the family were not originally from Northern Ireland. They worried about fitting into a new neighbourhood.

"Well actually yes, we took a long time thinking about it, because our main concern was the area of the houses. We are foreigners and because it is so close to the peace wall, I struggled with this, but then we talked about it and decided to do it. But it was because we cannot afford to pay a full mortgage, so it was the only opportunity to have our own house, because, you know the scheme is so family friendly, because it so low cost. They did not accept our application at first, so we were put in reserve list, then Tom (the HFHNI scheme manager) called us and said if we were happy, we could take part in the scheme. ….that was the story."

In the end, however, they weighed this up against what the scheme had to offer, especially the fact that it gave Karl and Irene a first chance to become home owners:

"Well it's actually because we cannot afford to pay a full mortgage, so it was the only opportunity to have our own house, because, you know the scheme is so family friendly, because it's so low cost"

The family felt that the scheme had other qualities related to participation and involvement when compared with the normal home purchase process.

"We know the house very well because we are building them, so we can feel it's our house because we know every plank and window because we fit them. That's the good thing about this scheme, really good thing. And we know our neighbours as well already, so another good thing".

The family did not feel that they would miss much from their old home and were very excited to move to Green Street.

"I don't think there is any particular thing we will miss because.... The house is obviously bigger and has a garden; we don't have a garden here, we are looking forward actually. It's going to be cheaper for us as well, that's a good thing for us. We are looking forward mostly".

All in all, there was only one family whose hearts were set on the Project from the start, with the other families having experienced some doubts and uncertainties about whether the Project was a good idea for them or not. Significantly, the innovative energy system was not a primary attraction for the families. Only one family expressed an interest in it before the move; they perceived this more as a strategic advantage in choosing to join the Project:

"I said that if they are doing something like this, then they will not want something bad for us or anything, it is going to always be better. I said that I would be happy working on something like this."

The new energy system was thought to be a safer bet through being part of a spotlighted scheme for this family, rather than being a means by which they could become "greener" or save money.

4.2. Families in the spotlight

The scheme attracted considerable media and political attention from its inception through to its final launch. There were sound reasons for the media's curiosity and politician's expressions of interest. The Green Street pocket neighbourhood was one of the first Community Self-Build projects in Belfast, and these are not without some interesting advantages and risks:

"Community self-builds can have a number of advantages over individual self-builds. There is the opportunity of growing a strong community through building homes together. Self-builders are able to take part in the decision not only of the design of their home but also their community. For example they can choose to incorporate a communal garden, a community room, shared utilities (e.g., washing machines) and/or pedestrian friendly streets. They can support and advice each other in the process of

building their own home. They may save money through bulk purchase of building material and through recommending reliable contractors to each other. Whilst these are significant advantages community self-builds do not come without challenges. The communal decision making process can be difficult providing a platform for disputes and conflicts. Any Eco-self-build housing venture would need to address this in order to ensure success. "(Broer & Titheridge, 2010, p. 2088).

This particular pocket neighbourhood also came with an unusual "package" of characteristics in which the residents were:

- Capable of contributing to a self-build in terms of labour and gradually growing expertise
- Able to access the financial resources for a self-build
- Able to lever in the required specialist expertise
- Willing to cooperate with others and with neighbours in the building of a new community

Broer and Titheridge estimate that fewer than 5% of UK households meet all of these criteria. In this context, therefore, the Green Street residents can be appropriately considered to be pioneers.

Some of the publicity and interest also stemmed from the innovative technology used in the build. These houses could, potentially, provide a ready-made solution to fuel poverty in Northern Ireland, at least where new-build properties are concerned. It was for this reason that the Department for Social Development Northern Ireland (DSDNI) invested funds in the scheme, since DSDNI are the government department with sole statutory responsibility for tackling fuel poverty.

In addition media attention focused on the symbolism of an innovative project being situated near a peace wall, although this was never a matter of remark for the families themselves.

The level of media interest grew over time, so that when the families were preparing to move in, public expectations were running especially high. Local newspaper articles used increasingly emotive expressions to describe the Green Street Project. In the region's best-selling newspaper, a 200-word article on the Project described it as "ground-breaking", "slashing energy costs", "revolutionary", "one of the most energy efficient systems in the world", "costs at rock bottom". In the pre-Occupancy Evaluation, the residents themselves expressed their awareness of this hype, some of which was infectious in the best possible way:

"I think the whole thing is, we have been down, we have taken part in the project, we have met so many different people, from - you know - different parts of the world, and they have come from their own wee country to work on your house. The enthusiasm of those people really amazes me, they are prepared to give so much time up for the Habitat project and wider, it just blows my mind. So much so that when we finish here, and move in, we are going to get involved with Habitat and work on the new site that they have in Templemore Avenue. I hope in the future that we can join one of their big builds; we do definitely want to become more involved. But there is the stress element, it does happen, I wasn't going to let it happen, but it does just have this habit of creeping in and biting you in the bum, and letting you know that this isn't going to be a normal move, things will happen. We are just trying to take it in our stride."

As noted by Bell and colleagues (2010), the fact that the project was subject to intense scrutiny by scientists may also have raised expectations. We were less visible to the householders on a day to day basis than were our colleagues evaluating the technical aspects of the homes; their equipment was visible, and monitors could be heard whirring occasionally; families did express mindfulness of this at post-occupancy evaluation. Whilst always committed to maintaining good relations with the families, the team from Psychology at UU took care not to become involved in trying to find solutions to early teething troubles that the families experienced, and endeavoured to maintain roles as participant observers at all times.

4.3. The build

Inevitably, families got to know each other well during the build, which they all saw as a significant advantage:

"It's good getting to meet your neighbours and stuff before you actually move in as well."

"You know who you are going to be living beside, there is no surprises like.

"Getting to know people and seeing how your house is getting built from like, the smallest parts so you can get involved and help your neighbours even to build their houses and seeing everything up and down and get all together, into this. That is what I think is the best thing."

"You get to know your personalities and stuff before you actually move in."

"We got to know are neighbours and we actually became friends with most of them. So we won't feel alone when we move in and we can always get help if we need it, it will be a good thing."

The building process itself proved unexpectedly transformative for some of the families. In some cases they felt they had changed the way they managed situations:

"To a degree Habitat has changed our lifestyle. We have both gained more confidence and that is something that I have shared with a lot of others. I would be inclined to speak out more and voice my opinions, whereas before I just have not said anything. I never wanted to rock the boat. But now I feel that unless you do air your views and do speak out, people are not going to know your concerns and I hope that people don't think I am saying it just for the sake of saying it, you know, that they think "he has something to say". I always believe that you need to speak your mind and be clear about what you are saying, so that people do understand that you do have concerns and try their best. Over the year we have gradually gotten more and more involved."

In other cases, the changes were more physical!

"The first time that I went down to the site, I will say I went up the scaffolding and I found because I was carrying far too much weight then, trying to get from one part of the scaffolding to the next and whatever, it was murder, I was murdered. That convinced me that I needed to do something. I changed my life style, my eating pattern. I have lost weight and I can do it all, but don't ask me to get down under and sandpaper skirting boards….My lifestyle just changed completely, you know, from then and being involved down here and just identifying what I wasn't able to do, because I was carrying that weight. The friendly banter with the boys down there "you need to loss some of that weight"...maybe I do need to lose some of this weight, there was something about it and knowing I can do things...Now I can put overalls on, it would have been an ordeal, I would have had to have someone to hold onto, couldn't bend over to tie my laces, I would have to go and sit down. It was through working down there that changed it."

For others it was more a sense of personal achievement:

"Actually taking part in the build of the house was a big thing for me. I was afraid of heights and then we had to get up on the roof for the tiles and stuff and that was a big achievement and just being part of everything, putting the windows in, the interior walls…just being part of it all."

"I put the roof on our house. I really did!"

"And I put the insulation on. We got a lot of experience."

At Pre-Occupancy Evaluation, all of the families felt that the collective building program had cemented good relations between themselves as a pocket neighbourhood, but one family also mentioned bonds that were developed with volunteers:

"Having a relationship with the people that help to build your house, people are very keen to help. We still have contact on Facebook with people, and they ask how is it going and if we have any pictures. So everyone is still caring about us, even if they are not here, they still want to get some more information about this. It is the relationship with people, it is different from the day-to-day things, people are willing to help for nothing for you and being so excited for you, I think that's really nice."

Respondents were asked about how Habitat for Humanity, as an organization, had performed during the building process, and comments were uniformly positive, with frequent mention of the HFHNI Green Street Project manager, Tom:

"They were very, very helpful and in the early stages when we came in….I felt that the guidance was there, you know: 'You need to do this, this and this, application forms go here, come back to us, this is the bank and they will guide you through what you need to be doing'. That was all fine. That was spot on. The big thing was the Tom O'Dowd approach. I have purposely kept every email that Tom has sent me with snippets of information, anything at all. If I was to text Tom. I would replay his answer back … the information that you are getting through Tom, the communication brought to the families, has just been excellent."

However, on reflection, there were a few additional services that would have been appreciated, for example more information on the fees that would have to be paid when the home was purchased, especially since the time coming up to moving was expensive, even without having to cater for these:

"Maybe telling us about the expenses that you occur coming up to the end, the solicitor's fees and all, when we were applying for it. We weren't really told much about that. They should tell people more about it at the start and give people a chance to save."

Given that only one of the families had ever purchased a house before, these additional expenses were, understandably, new to them and the additional amounts required not insubstantial.

4.4. Preparing for a new energy system

Interviewer asks: How do you feel about having a home with no central heating?

"Alright like, but I still don't understand it".

It was only during the building phase that the realities of the new energy design became evident to most the residents. For some, they only realised that they would have no central heating after they had committed to the project:

"And that's what I said when we first took building the house. It never dawned on me that there was no heating in it and then I started to wonder where the pipes were. And then it was at one of the meetings at the Oasis, they said 'Well there is no heating in the house'. I thought this is going to be good! But you did panic a bit, thinking how is this going to work? So when we first applied for the house we never knew there was no heating in them."

However, the excitement was palpable in some of their accounts of the energy system's installation process:

"We don't know what is ahead of us. The big plus is the water is now working, I don't know whether the others were down but I know I was down when the guy was connecting the solar panel. He came down and said 'Away and try that, but just be careful'. I wondered what the '"be careful' was about, because all I was going to do was turn on the hot water tap. I then seen what the 'be careful' was. It was very hot, it was unbelievable, I couldn't believe it. If my father was alive today he would say 'that's what everyone should have'. He was a great man, a simple wee man. 'Wind' he would say, 'they should be harnessing something up to that wind, the sea, they should be doing something with that sea, the tide, the currents, the sun'. If he was down to see that he would be in his element, he would be rubbing is hands; 'Look, free! Hot water for free' he would be saying. It's just amazing it really is. I couldn't touch the hot water that day…Now whether or not they would be like that if it's overcast I don't know. But the towel rails were throwing out heat..I would just love to see the whole thing coming together and working, you know."

"You asked earlier about who was excited, I am like a big child now…it takes an awful lot for my wife to get excited, but she is excited, she is so excited about the move."

"Well I am really excited about the central heating, warm water because it is free; it's working really well so far."

One of the families looked forward to living without radiators:

"We like to move furniture around so we will have the space to do it. We can't move that piece there because of the radiators, we can move it here, and there will be no problem. There will be kind of a bigger space, because if you have a radiator you have to keep it uncovered, so it will be kind of better."

However excitement was tempered by the usual trepidation at the prospect of a move:

"Just some concerns, because no radiators, that sounds strange you know… how do you warm up your house, you know? We spoke with the designer of those houses, so he said 'I could show you the already built house with this technology and it works very well', so we will just see what happens. Everything is going to be fine."
"Exciting and tiring, because we have so many things that have to be moved and transferred, but we are really excited because it is the first house in our lives that we can say, this is our house, you know, not rented. It's exciting, we will see."

"There seems to be something each day that just sets you going, you say, 'O dear, this needs sorted, that needs sorted'. I sat down at the computer and typed out everything that needed to be done, change of address at the back, insurance, all that needed to be done and there are wee things there like that, that creep in and just upset everything"

For the single parent family in the group, anxiety about coping with the move was understandably greater:

"We have to ask a lot of friends for help because we are a single parent family and we are alone so we have to do it all our self. There is not a man to even do the decorating in the house - we have to do it all ourselves, so it's, kind of hard."

A final concern focused on the sensor equipment that had been installed in the homes, some of which was considered intrusive and liable to damage:

"The only real thing would probably be the wires hanging down from the ceiling, you know, the sensor wires. The one in the bathroom is hanging down over a foot, we don't know if it can be tied up or…it won't really annoy me like but…."

"I don't want the wire there."

" We talked about it in a meeting with Habitat last week but he still hadn't got back to us with an answer, before we actually signed anything."

"It wasn't just that though, there is a wee sensor in the living room as well."

"There is no wire hanging down in the living room, but there's like a wee transmitter which has to be put at shoulder height somewhere, so they will probably just centralise it in the room. It looks like a walky-talky in the middle of the room. If it was sitting out of the way it would not be a problem".

4.5. The wider building process

Several families commented on the fact that they had been so deeply immersed in the construction process that they felt confident that they were moving somewhere that was well built and carefully designed. They also felt confident of being able to maintain their own homes in the future:

"Rab said to me….you have the satisfaction of knowing if you want to do something in this house you know where there is an upright in the wall because you have measured all the walls'. We know what's in the walls; we know everything about the house."

At the point when they were about to move in, the families felt that the building process had gone in a manner which they had expected, and that they had experienced sufficient support from Habitat For Humanity during that time:

"It went about 90% as we had expected, just a few teething problems and stuff with delays, but pretty much what we expected."

Some would have liked more opportunity to decide on certain features of the house . For example, the living room fireplace was positioned in a corner and not in the centre of a wall; this created problems for arranging lounge suites and other furniture; it transpired, however, that most of these design features were not so much aesthetic as central to the thermal design of the house and so could not be altered. Other features could have been altered though. Since Clanmil Housing Association became part-owner of the properties when the families moved in, and will remain so until mortgages are fully paid off, the Association took more than a passing interest in features of the homes. This stretched to items such as carpeting, which some of the families thought unnecessary.

"I feel that the home owner hasn't had as much say… we are buying half the house, Clanmil have had a lot of say and plus the model of the house, everything seems to have had to revolve around them, it has to be this, it has to be this, the model of the house…….we are buying the model, you know, it would have been nice for us as home owners to have a wee bit more say….your house is a wee bit different from next door because you wanted this and they wanted that, but sometimes that wee touch makes all the difference because you have added that."

"It would be good for us to be able to pick the color or something, just stupid things but it is kinda….We wanted to actually put on our own tiles but they are putting on the white ones and we wanted a different color, if we want a different color we will have to break the white ones on the wall which will ruin the wall and we will have to put then the other ones, but I don't think it is a big problem because I know that they have to get it to a certain standard, so I don't think it will be a problem, but if we could maybe pick a color of a kitchen or something, it would be much better".

This tension between what residents would have liked and what they were provided with was unfortunate in several respects. The ethos on which Tyrone Timberframes usually operates is one in which a client designs the house of their choice after which TTF builds a low-carbon version of their design. It would have been relatively easy for this to have been achieved, at least in some of the more minor features of the Green Street homes. The transcripts made clear that what were (on

the face of it) mundane elements of the build, where choice would have been relatively unproblematic, became some of the more significant disappointments for the families.

Further on this issue, the properties were provided with identical electrical appliances such as cookers and fridges i.e. these were not items that families could select for themselves. In some cases they were not suitable for a family's use. One of the householders also pointed out during the build that the appliances selected were not of a high energy efficiency standard, which made them out of kilter with the whole ethos and design of the low-carbon homes.

4.6. Household wellbeing before the move

We asked families to complete a health and wellbeing questionnaire before they moved from their old homes. This was done anonymously and the questionnaires posted back to us. We used the Warwick and Edinburgh Mental Wellbeing Scale, which is well known as a general and non-intrusive measure of people's current frame of mind and outlook on life. Table 4.6 presents some of the results.

These results suggest that the families were in good mental health with scores on all 12 items above average. Whilst their energy levels were low and they were feeling a little short of ability to deal with problems, both of these could be accounted for by the fact that they were approaching the end of a long building process and were simultaneously having to make final arrangements for taking ownership of a new home and relocating to it. These were also households that felt a particularly close bond to their families., were optimistic, cheerful, and confident.

Table 4.6. Average scores on the WEMWBS (5 indicates highest level of wellbeing)

Item	Average score out of 5
Optimism	3.6
Usefulness	3.0
Relaxed	3.2
Interested in other people	3.6
Able to deal with problems	2.8
Energy levels	2.8
Thinking clearly	3.4
Feeling close to family	4.2
Confidence	3.6
Able to make up your mind	3.2
Interested in new things	3.2
Cheerfulness	3.6

As part of the same anonymous questionnaire, we also asked the families about their attitudes to their *curren*t homes i.e. where they were living before they moved to Green Street. Results are contained on Table 4.6.1.

Table 4.6.1. Average ratings for the "old" homes (5 indicates the most positive rating)

Item	Average score out of 5
Comfort	2.4
Attached to this home	1.8
Difficult to manage the home	1.6
Enjoy the neighbourhood	2.4
Relaxed at home	2.2
Worth all the effort and expense	1.8
I know many people in the area	2.4
Gives me a sense of pride	2.2

Whilst their old homes were rated as reasonably comfortable, and there was a sense of neighbourliness, there was little sense of attachment to these homes (all of which were being rented), and they were considered relatively difficult, expensive and effortful to manage.

4.7. Energy expenditure and heating regimes in the "old" homes

We also asked the households to estimate how much they spent on domestic energy, and whether they were using gas or oil for central heating in the old homes. Two of the families used natural gas for their central heating and three used oil. All five families had full central heating with radiators. Taking the average of all 5 households, the estimated annual heating costs of the households was £900 per annum. The average estimated annual electricity bill was £530. In total therefore, they estimated that they were spending an average of £1,430 on their domestic energy. This ranged from amounts of £900 to £2,000 across the five families. Two of the families had "often" gone without heating in the previous winter because of cost.

Two of the families had damp and also mould in their "old" homes, and 3 experienced significant problems with condensation. In terms of thermal comfort, we asked the families how often their homes were a perfect temperature in the winter (average 40% of the time) and in the summer (60% of the time). Only one family expressed dissatisfaction with the amount of hot water available in the "old" home. Similarly only one family had concerns about the air quality and ventilation in their "old" home. All of the families found it either "easy" or "very easy" to manage their heating and hot water systems.

We also assessed their attitudes to energy efficiency measures, asking how much they thought a variety of home improvements might save them on their energy bills. Their responses indicated a uniformly high expectation of energy efficiency measures. For example, all five households thought that wall insulation, loft insulation and energy efficient windows would reduce their bills by "a lot". Likewise, all of the families believed that thermostatic controls, switching appliances off standby, heating only the amount of hot water needed, and heating only those rooms being used would save either "some" or a "lot". They were also knowledgeable about this issue, with only 4 "don't know" responses given to a total of 60 energy efficiency questions.

4.8. Summing Up

In summary, the Pre-Occupancy evaluation indicated that the entire process of applying, being accepted, building, and then preparing to move into their new homes (a process which unfolded over a period of more than a year) was well managed; support was provided at almost every occasion when it was needed. If similar schemes launch later on, most of the minor elements that led to disappointment or stress can be readily addressed, including a little more information on pre-move expenses, and more choice offered to residents in terms of colour schemes and appliances. Opportunities and gains from being involved in the building process far outweighed the shortcomings, and this applied to all 5 of the families without exception. Their "old" homes were satisfactory in many respects, but there was little feeling of attachment to them, they were not considered worth the effort and expense of maintaining them, and the levels of thermal comfort were rather low in both summer and winter.

Chapter 5: Results

Post-occupancy evaluation

"Reducing electricity demand is both more problematic and more urgent than the issues surrounding gas or oil use. It is more urgent, because the present carbon intensity of electricity is high. It is more problematic because of the sheer number and diverse types of electrical appliances and equipment we use in our homes, and the lack of coherent national policy to reduce electricity demand. This is a huge omission from the mainstream UK policy." (Boardman, 2012)

5.1. The move

Families moved into the new homes in June 2011. This was six months later than they had originally thought, which caused problems for some families

"The delay cost…..for us around £1800 for rent for three months because it is £600 for rent per month, which is loads more because this house is really big and to run the heating system it costs us loads. And then while we were waiting to move, we ran out of oil and we didn't know, so we had to buy oil, even if we were moving in a week or two…we had to buy it because we had to have it for hot water."

but not for all. Families with children felt that the move being delayed until after Christmas was a mixed blessing.

The move itself was marked by considerable publicity and a celebration day (see Figures 5.1 and 5.1.2).

Figure 5.1. Invitation to stakeholders and volunteers to attend the moving in celebrations

Figure 5.1.2. The day itself

Officially, the residents became tenants of Clanmil Housing Association when they moved in. This new relationship was, initially, somewhat confusing for the residents:

"Clanmil hasn't really been as much a partner as we thought. You know I did complain initially, their partnership with us seemed to be very silent, not that we worried about that mind you. We were happy that this is our home and there's not always someone floating over your head, but from our initial contact with the young girl up in the Oasis center, a one off, and then on the day that we moved in, and I think I said to you, there was no one coming over and introducing themselves. The Chief Executive was there that day, you know. So then when a problem arose next door, they had all sorts of problems with their plumbing and everything. When she phoned the number which she had been given she was told that because of her connection with Clanmil, and the shared equity, she shouldn't have phoned that number. So in a booklet, there was a whole big ream of stuff with an emergency number. If we were told at the start that your case is different here, shared equity yes, you're technically the owner, basically you're the owner and you have to take care of different stuff. It was an experience, another eye opener. We had to accept that we are no longer in rented accommodation. We always knew that but I thought when we entered into this it was something different."

A lack of preparation and communication on the part of Clanmil appears to have caused residents significant problems in the early days. Since these were the times when most problems emerged (as they do with any new house) the need for better relationships between the Housing Association and the tenants appeared to have been overlooked on both sides. Although the residents had been contacted by Clanmil, and had been given a "whole big ream of stuff", it was one of many reams of paperwork which residents had dealt with before and during the move. Something more personalized (and timed to coincide with their move) would probably have worked better, especially given the special status and media attention that these new homes were being accorded elsewhere. That being said, responses to the Pre-Occupancy Survey indicated very high levels of knowledge about energy efficiency in the 5 families, long before they had relocated. It is likely that a great deal of the information imparted to them about the energy efficiency of their new homes had been absorbed, although perhaps not the technicalities related to their future maintenance of thermal comfort.

5.2. The first summer

Families moved in during the summer, although this particular summer in Northern Ireland was one of the coolest and wettest in recent memory. Nevertheless, the Green Street houses were warm inside and occasionally had to be cooled down. Families relied on opening windows for this, as well

as on the ventilation system. The latter was used most often when traffic noise from a nearby busy road was troublesome. Even in the first weeks, the families were mindful of the cold weather ahead, and recognized that nothing would become clear until they had got to grips with a winter:

"We are lovely and warm and hot water is always in supply, but the big test will be the winter months"

As winter approached, cold temperatures became more of an issue, as would be expected. However, this highlights a less commonly noted point: the season in which residents move into low carbon homes is a vital key to how they can be best supported in their transition to low carbon living. In the case of the Green Street residents, they had some opportunity to familiarize themselves with their new energy system before they needed to rely on it more fully for keeping warm. Where relocation occurs in the depths of winter, it may be necessary to provide families with a more intensive support system that allows them to manage teething troubles without this causing health risks or discomfort.

5.3. Teething troubles

Initially the energy concerns of families focused on how much they were spending on electricity. Consumption could be monitored easily through their initial Pay as you Go (Keypad) meters, which were subsequently replaced with SMART meters and inhouse displays. All of the families had used Pay as you Go meters in their previous homes, and so they could readily compare what they were using in the new home with what their meter had needed each week or month in the previous house.

Since most of the families had initial teething troubles with the energy system, they all experienced an interim period that was costly in terms of electricity bills:

"In the beginning we were just pumping money in all the time, you know? You were just constantly putting money into the electric and I said 'Well I don't mind that's one of the things that I do pay, and my husband pays the rest'…and I thought 'Is it me?' Because you are just pumping it in. But then one of the other houses happened to say, and then someone else happened to say, and we realised then that we had to have this looked at"

"The saving, the big saving that they talked about. Oil or gas suddenly was being taken away was good but we noticed there was a big difference in our electricity charge. They went all out to try and get to the bottom of it, from actually looking at the hot water and the cut in, the thing inside the solar panel heating the water, and in the winter time you just don't have enough daylight and sun as you would expect".

"I think at one stage it was around £30 a week.

"You are just putting it in all the time"

"And from being used to paying around £15 at most"

"We knew the heat circulator had to be on all the time but it wouldn't be taking the electric that we were putting into it, sure it wouldn't have?"

"And the dryer, I wouldn't have said I would have used it a lot. It's mostly on at night now when we are going to bed because you can't have it on during the day because you can't hear. That is because we had never an open kitchen before and we don't mind that. Same as you heard the kettle earlier…so really it's the best time any way is to use the dryer at night. But it all settled down when we got it sorted out"

The families' previous experience with Pay as You Go meters, and their decision to have these installed in their new homes while they waited for a SMART meter, was very fortunate. They were able to identify teething troubles with over-consumption of electricity almost immediately. If they had opted for a conventional electricity meter that would have been read after a quarter, the impact of these early problems would have been of a totally different order. Even so, one of the families had a particularly long period of expensive energy costs:

"They had wired the Solarmax (solar hot water system) wrong somehow, so it was costing us near £30 a week in electric, which again it was supposed to be saving us. And it is costing us near double to what we were paying in our last house…But it has been sorted now and it's not just as bad. But for about four or five months we were paying double the electric. "

After their SMART meters were installed, the opportunities for monitoring and managing their electricity consumption increased significantly. Some of the families relied heavily on these to help them further understand the energy system:

"He was obsessed with it when it first went in. He would run about turning everything off, things you even need he was turning it off. He was nightmare. But he's not so bad now, I think after me shouting for a few weeks, he stopped (laughs). But you do be more aware of what you are using, when ever that is going up past what it should be, you do be more aware. It's good."

"The wee SMART meter is very helpful, excellent"

"Even like taking part in a SMART meter trial. I think t would be so much better for everyone. Even when I move away…I want to have a SMART Meter in my house because I wouldn't know what to do without it."

The SMART meter and in-house display also proved useful at the start of winter, when some of the initial problems of the summer months re-emerged as winter heating was needed:

"That was the big reason that we were able to look at it last winter and say "OK, hang on". And when they came out to interview us, we were able to say look, this is what our electricity is costing, this high, and they said It can't be' And we said 'Well here is the evidence' ".

"So the big figures for savings that they talked about, we were able to blast it out of the water and say 'Well let's be looking at this'. So they sent someone out to do a reconfigure of the hot water, and then the designer of these houses came and looked at these things, the recovery system. He explained it better, and told us about introducing a wee bit of heat, you know, because how we were trying to heat the house was not effective enough."

"It was just eating it. I'm glad they found it out because I was saying it can't be, I just put money into that and it was just pinging *(pinging is a reminder that the meter is about to run out of money)*and I do not like to hear that thing ping. In our last house, I would have had it always topped up. It was good to get to the bottom of why and then the thing settled down."

Given these experiences, it would be ideal if SMART electricity meters were available to residents of homes using these sorts of innovative energy systems from the start. Failing that, Pay-As-You-Go (Keypad) meters seem essential.

By the end of the winter some of the families were content with their system:

"Heat wise? Great through the winter. We came in early summer , the house was good, then it dipped a bit in the winter and we thought "What's going on?" but we weren't told then that we had to use a wee convector heater. Then we used the electric fire more downstairs, and in the bedroom we put a wee convector heater onto a timer, half an hour in the morning, half an hour at night. Just through that, the heat goes out from our bedroom onto the landing. I find it different going into other people's houses now, and their heating's off. I automatically feel cold. But in here you come in and it's just warm all the time."

"It's comfortable in here, but when visitors come in its just so warm for them. They probably come from a house that, at this time of the year, they probably knock their oil off and it only comes on certain times so it's a wee bit cooler. But here, it's a constant nice temperature…. Maybe it's just us, but we feel more relaxed and comfortable. I don't know, in our other house we wouldn't have come in and sat as much. In the afternoon when the cleaning and all is done, you sit and you enjoy this house. Whether it was the coldness of the other house, I don't know what it is. With here you just feel happier**…**You can be sitting there at night, and that fire was going, and all of a sudden you had to turn it off…It was too warm. Which is good, like."

Similarly one of the other families were quickly satisfied with the energy system:

"Everything was so easy; it makes everything so much easier, you don't actually…well you know the way during the winter because its cold you have to put your central heating on at a certain time and turn it off? This one it is just constantly warm and you don't have to worry about it. Even if you are not home for quite a while, you would still find it to be warm, so I think it's perfect."

For others, the early disappointments were moderated by an awareness that some of the difficulties were heat management problems which would be mastered over time :

"We are slightly disappointed with the house performance during the winter time but that was the first winter so we will probably learn a little bit. The house for our daughter upstairs was quite cold. The small room at the far end dropped once to 14^{o}c…David Maxwell from Tyrone Timber Frames gave us some tips on how to keep the house warmer, how to use extra heat input and that…and it was slightly better but in general I was a little disappointed. Probably we didn't understand at the beginning, when they did all the introducing on how the house works. In the beginning they promised us that it would be 21^{0}C all the time here. The perfect house doesn't exist, there is always a loss of warmth from somewhere. Downstairs it's ok, we are happy with the downstairs. Then again, the thing is that you have to learn to live in this house, temperature varies so you can't close the doors because one room can be really cold and one can be really warm. It's not a conventional house."

For other residents there have been disappointments, but these have been coupled with real attempts to understand where problems lie and what can be done about them:

"We will see when they fix the window frames, because the glass is actually really good, it is performing really good, but the frames I think are bent or something. When your hand is close, you feel the cold air coming into the house. Because the house is air tight, it stays here, you have to use the (points to gas fire)…over time to try and keep the heat in. But that's, I think, a construction fault. You know, now I know how important the details are in passive houses…you can't rely on volunteers in my opinion, everything has to be perfect. Air tightness is crucial, truly crucial. Between the first house and this house there is nearly double the difference in air tightness, the other one is plus 1.1 meters per hour air leakage this one is 2.4, it makes all the difference in the winter. Now it's OK, the temperature is 5 or 10, the house is really good, no need for extra heat. The coldest days are the worst for us you know… they should inform us more, tell us more about passive houses. The best way to build them is to build them like bungalows so the sun can get around them all day, heating them. It's not the best design for a terraced building's because you only have one wall here facing south and that is the only warm wall actually. Sun makes all the difference as well, the house reacts really fast when there is some sunlight, sun warmth. It will heat up really fast and stays, but it's just one wall you know? Four walls would probably work far better".

The same determination to monitor, alter, and manage the energy system is reflected in this excerpt from one of the other families:

"Next winter, we will make sure we have the fires in. Because for the first couple of weeks this last winter it was cold, and we were trying to mess about with the vents and stuff, turning them up and down and wondering about that fire…but we got a couple of halogen heaters in and just put them up the stairs. We just turned them on before we put the kids to bed and then in the mornings, because we were up first. We put them all on again before they got up….It was actually easier to adapt to it compared to what I thought it was going to be, so it was. It was just in the winter it was a bit of a pain, but it was just taking time to get used to. It was a lot easier than I thought it was going to be, so it wasn't too bad. The way it was laid out to be to us was that it would not get as cold as it was. And it did get cold like. We were told that the fire in the living room would heat the whole house but it didn't, it just heat here (living room) so we had to put heaters upstairs as well…. I would put the halogen heater on in my room after I give them a bath to make sure the room is warm enough, but it's never really on, only for 10 minutes, if even that. It's only on because I'm thinking that it needs to be on, when it doesn't"

The above 2 segments from the transcriptions illustrate the extent to which building and then living in a house of this revolutionary nature has led not only to teething problems, but also a determination to understand the systems being used so that they can be used to best advantage in future. It also raises the important issue of whether a sequence of ever-changing volunteers can or should be relied upon to assist in building homes which have such specialist requirements.

A similar determination to master the system can be seen in comments from another of the families:

"Before the winter they adjusted that ventilation system to perform better. But first when the cold days came we didn't know how this thing worked or what the settings were supposed to be, so that system was actually blowing cold air into the house. And because the house is air tight, it was just cold inside. If you put cold air inside, cold air will stay, like the fridge. And if you put warm air in, it will stay as well. To know how that ventilation system works is important. I have a better understanding of how it works now, with a bit of time and practice. You need to live in the house, you need to be active. Like all the cooking in the house, that is extra warmth. For example, we went on holidays for 10 days in January and because there is no central heating you can't leave the

house with settings on…the temperature drops here to 12^{o}c. It's not just the air; everything is cold, even the furniture. And it takes a lot of time to build the heat again…. Yes, I think I will phone the guys at Timber Frames to ask how to react to the temperature change outside. They changed the filters when I contacted them last time, but you have to learn yourself. Every house is different, they react differently."

For one of the families, difficulties had never been satisfactorily resolved, although they are overlaid by several other construction faults:

"It's ridiculous…we are actually dealing with flooded drains again today. This is the third time now in a year…problems with the sewerage, the drains are just a complete nightmare. The electric was atrocious to start with because of something to do with the boiler. What else has went wrong? The windows, it was ridiculous, it's supposed to be an energy efficient house and it's just not. And everyone fobs you off from one person to the next. When it's windy, those blinds and everything move. Yeah, it's a bit disappointing."

It seemed evident that, for this family, these ongoing issues (not all of them related to the energy system) meant that – even where systems had been mastered with time – there was little sense of pure contentment:

"To be truthful, it works, it's OK yeah. It's not what I was told it was going to be. I will not be able to sit under one of those heaters and so on. I will say it works and I have kept an eye on the house. I have got temperature gauges throughout the house now to let me monitor it, the outside temperature and inside temperature. And I will say for the house, it does definitely help. What we were told was that if it was 40^{0}C outside it would be 21^{0}C inside, and if its -30 outside it would be 21 inside. And I must say it is almost completely true to the word that it keeps its temperature in here regardless of what it is outside. I'm happy with the system. I know better how it works now, that I can turn it up and down and so on, I'm happy enough…..It is a better house, it just needs a few things along the line you know, like any new house I would imagine. Like a silicon fix would fix those windows, I know it will. It's not the back ones actually, it's just the front ones really, and the upstairs bathroom window. They have a silicon fix down the side of them near the brick and it's been put on too flimsy basically. Once it's contracted with the heat…or expanded and then contracted with the cold, I think that it has just pulled off. So really now that's triple glazed and if I was outside and you were sitting on that settee and I was to just talk or whisper, you would hear

me clear as day as if the window was open. It's strange, like, and I know it doesn't sound like a big issue. And plus when it's windy, and those are big heavy blinds, but when it's really windy you would hear it moving, so there must be a big heat loss issue there."

Two of the five families encountered problems in the build quality that were not related to their energy system:

"There were also some accidents with the kitchen ceiling, it fell down. Well the pipe broke and you can still see the water marks on the ceiling…it all fell apart into the kitchen …well it was solved quickly. Yeah we were happy enough"

Summarising what the families told us, they all moved into their homes confident that they knew how to manage and maintain them, since they had helped to construct them and knew a great deal about how they were designed. It was perhaps this (very appropriate) confidence that led to initial disappointment for most families, when they found that they were unable to regulate their electricity use, and also unable to figure out why. The families felt that they had not been sufficiently prepared for the fact that they would have to use extra electricity to heat their homes. They harboured a mistaken impression that their homes would remain warm all year around with no additional heat sources. The most likely explanation for this was that families were also very preoccupied with hundreds of other matters during the building process and had become focused on the overall media message "Homes without the need for central heating".

A particular excerpt from one of the families at their one-year assessment indicates this:

"We knew and suspected that it was too good to be true, come winter time something will be required, but we weren't told and David Maxwell from Tyrone Timber Frames had admitted once again, like that night of the first meeting with you two girls from the University; that when temperatures do drop, you have to, he used the term "introduce heat to the house. And all we had to do, I couldn't believe it, was a half hour in the morning before you get up to go to work, a wee convector heater came on and then that was it off until we were going to bed at night and this fire down here was enough".

The "two girls from the University" were indeed at the meeting, and our impartial recollection is that the TTF representative was transparently clear about the need to introduce small amounts of

heat during winter. On the face of it, it is surprising that the households took rather long to begin introducing heat in a routine basis in the winter. However, meetings such as the one referred to above were also taken up with many other matters, such as what the next building phase would be, where ventilation ducts were located, who was volunteering the following week, where fireplaces and furniture would fit, whether larger size openings could be made in kitchen work surfaces, and much more. Whilst *we* understood David Maxwell completely, it was inevitable that the residents themselves would have been thinking of many more things besides his message concerning the need to introduce heat. We are, of course, also energy efficiency specialists, which at that time none of the families were. It is likely that the families needed more messages about introducing heat selectively, and these could probably have been more memorable if they had not been interspersed among many other more pressing topics during the build.

All of the families commented in one way or another on the extent to which controls had to be manipulated manually, on an almost daily basis, to maintain temperatures at a steady state.

"I just have to control more for the boiler, make sure we have enough warm water and things like that. In the winter because there is no automatic steering box to just turn on that manually (gas fire), that is the difference. They should think about it I think, to put some sort of automatic setting for the heating because when it's cold you just have to wake up and turn it on and go to sleep again. But I understand that they want to cut costs a little bit so that's probably why. But it's not very convenient to turn it on and off".

Some had already linked additional heating devices to timers, and one suggested an automatic system that could respond to temperature falls and rises:

"The only thing that annoys me about the winter is that you can't set your heating to come on in the middle of the night to heat up the house during the night. But that's the only thing I don't like about it. It's too dangerous to put the halogen heaters on in the room while the kids are in the room, in bed. In case there is a fire or something. It would be the only thing, like. Even weather like that (rainy day), because it's not that cold outside, so in here's not cold at the minute. And that fire hasn't been on in about four weeks"

Whilst none of the homes had been fitted with automatic thermal control systems (which would have affected the price of the homes), these would most certainly have been welcome. In larger

housing developments for lower-income families, economies of scale may make automated systems more feasible.

When pressed, however, these are problems which have largely emerged as teething troubles during a first winter:

Interviewer: Would you say these are major difficulties? Have you found any major difficulties dealing with this new type of system? "No, I wouldn't say so."

5.4. Thermal comfort

Results from administering the ASHRAE Scale of thermal comfort to residents indicate that families have yet to attain perfect levels of thermal comfort. Table 5.1. shows the ASHRAE Scale results.

Table 5.1. ASHRAE Scale of Thermal Comfort – responses based on the 5 families

Winter	Living room	Main bedroom	Child's bedroom	Bathroom
Hot	0	0	0	0
Too warm	0	0	0	0
Slightly too warm	0	0	0	0
Neutral	**2**	**1**	**0**	**5**
Slightly too cool	3	3	0	0
Too cool	0	1	4	0
Cold	0	0	1	0
Summer				
Hot	0	0	0	0
Too warm	2	1	1	1
Slightly too warm	2	3	0	1
Neutral	**1**	**1**	**4**	**3**
Slightly too cool	0	0	0	0
Too cool	0	0	0	0
Cold	0	0	0	0

From the Table, it is evident that bathrooms performed very well in terms of perceived thermal comfort, being at perfect temperatures in the winter months and either perfect or only slightly warm in summer. By contrast, children's bedrooms only reached a broadly satisfactory level of thermal comfort during the summer months, and were consistently too cold throughout the winter. Living rooms and main bedrooms varied between being rather too warm in summer to being rather too cool in winter, seldom attaining fully satisfactory levels of thermal comfort in either season but not being markedly uncomfortable either.

Of course the ASHRAE scale is based on purely subjective assessments of temperatures. Technical measurements of temperature have also been recorded using digital loggers in the homes, and these will be evaluated in this report's companion evaluation, which is concerned with how the building itself performed relative to the design specifications.

5.5. Hot water

Overall, satisfaction with hot water was variable. Once initial (and costly) problems had been resolved, some found it ideal, others tolerably good. However, the dangers of water that becomes too hot for children to use unsupervised remain a serious concern.

Some residents believed that heating hot water was the primary reason they had experienced inflated electricity costs in the weeks after the move. For some, this resolved:

Interviewer: Are you happy with amount of hot water coming into the home?

"Oh absolutely."

"Probably suits us better because there is only the two of us."

"Yes with just the two of us. We would hear one of our neighbours say she could use more. But she has to bath the children and stuff. It's quick for us."

"But we are over the moon. I only use the bath twice a year, I don't get washed (laughs Yeah, the shower is so handy"

"But I mean the water is great, like. The shower is at a nice temperature, during the winter and all. Although I like it, it's just nice. And then remember the other week with the hot weather, the hot

water was scalding, I wouldn't let the kids near it in the wee toilet. We are not complaining. It would be hotter than normal and that's because of the good weather."

For some of the households, their water became too hot during good weather:

"The shower, and the upstairs bathroom, they have it set so that you turn your hot water on, you don't get that roasting hot, it comes through right away at a nice temperature. Whereas down here you are getting it roasting hot. See in that wee bathroom there, in the better weather, boy that water is piping."

One of the families was considering installing a solution for this, since water temperatures should ideally not exceed around 60^0C:

"The hot water works really well during sunny days like two weeks ago, it was like 85^0C, you could burn your skin, very warm. So we are thinking of changing the taps because there is no mixer, so we have rather boiling water or really cold water. You need to think about that, if you have solar panels, that it is crucial to have a mixing tap."

Although the families express tolerance for this , having areas of the house where children cannot be left unsupervised because of hot water that could scald them is not so much a drawback as a health and safety risk. The problem may be soluble with a mixer tap, but this still relies on manual control; the problem is preventable with appropriate thermostatic controls.

For one family the water was not as hot as they would have liked:

Interviewer: Are you happy with things such as the amount of hot water in the home?

"I think it could be hotter to be honest, but I think it's OK…"The boiler is a bit too noisy." (*this was probably a reference to the air source heat pump, since the homes did not have a boiler*).

Interviewer: Is that the system upstairs?

"Yeah, it rattles the door and vibrates…especially at night, it rattles the doors when you are sleeping and it wakes you sometimes."

Interviewer: Through the year has the system changed at all? Did it work better at the start or did things change as the year went on?

"The boiler was a bit quieter."

One of the families reported few problems with hot water to us, although this could have been because any teething troubles with it seemed insignificant given their other concerns with flooding, pipework and other problems:

"No, no complaints about the hot water system. It's like a backup system so like today if it's not sunny, tonight you can add settings for it to kick in when you want, so you will always have your water to a set temperature and the motor will kick in like an immersion heater, but its more efficient, I think."

"But that's for the shower…you can see the dishes sitting over there because I can't fill the sink with hot water because the drains are blocked, I have no water and the dishwasher is full."

"That's an outside issue".

"I know, but it's a year later and I'm still sitting with dishes because I can't run water into my sink. I can't use the washing machine either. That's the first in days I have put it on because I need to get uniforms ready for tomorrow. All the water keeps coming up into the sink."

"It's coming into the sink; it's all the same exhaust"

"It's like back to the old days, I'm going to have to go and use a launderette".

This account is central to understanding the composite of experiences reported to us by the Green Street families. Where houses were broadly functional from the start, and most features of their new homes were a source of joy and achievement, the teething troubles associated with calibrating a new energy system were quickly discounted, and could be placed into a broader perspective. However, when a house was perceived to be undermining people's normal routines and lifestyle, and when it made a practically functioning household impossible, any problems related to the energy system became marginalized, and any solutions to them seemed little more than marginal achievements.

5.6. Did families save money on energy bills?

Families varied in their views of whether their new homes were saving them money. In some cases, this was difficult for them to judge because of the way they had paid for energy in the past, which was on a trickle-down basis i.e. using Pay-As-You-Go meters for both electricity and gas:

"We think it is working out more or less the same. It's probably because we never had a bill for our heating; we just paid it as we used it so we never really noticed paying it every week. So we are not really noticing the big save. Maybe somebody gets a bill for their Gas at so many hundred a month; we didn't have that bill so we didn't really notice it."

It is fair to say that respondents were not especially effusive about the extent to which their houses were saving (or not saving them money), except in the interim adjustment period when costs were noticeably high. They only occasionally reflected on the fact that they did not need to spend money on oil or gas:

"We certainly don't miss having to flick the oil on"

"I was talking with a wee girl this morning and that's what she was saying, she paid £180 for 300 litres, and she is on her own with her wee son. She said 'I will top it up in another couple of weeks and try to get it up to six to 900' you know for the winter, like. That's what I say, you forget about that. And I find going into her house, its cold. We come into here with no heating and nothing being on and it's warm, we are comfortable."

However, some were more certain of savings when explicitly asked about this, although the comments on savings were not readily noted – they had to be probed for:

"Yes. We have saved, we have."

Oh! Definitely. Aye."

Others were more conflicted. They worried about the cost of the system in winter, and found it hard to reconcile this with how cheap the house was to run the house in summer. Overall savings were acknowledged, but the respondent concluded:

"It's more cost effective from my observations. Last month we paid £50 for our energy bill, but during the winter it was a £100. It balances overall in the year, but during the winter it is expensive to be honest. There is no real cost saving in this, in my opinion, because you can easily spend £600 on electricity and this would buy a whole ton of oil for that price and keep your house a nice cosy house."

It is uncertain whether the respondent had much experience of heating a home using oil, since the annual cost of oil-based central heating in a small home in Northern Ireland would have been around double his estimate. Demand for higher temperatures could perhaps also have been over-ambitious, since the respondent later expresses the view that 19^{0}C was too cold for bedrooms. The World Health Organisation recommends that bedrooms are run at 18^{0}C, and in fact the average UK bedroom is maintained at 17^{0}C (Uttley & Shorrock, 2008).

As already described, one of the families had experienced a long struggle during which they had been paying more than they had ever paid for energy before. This family also echoed the previous respondent's view i.e. that it is difficult to judge whether savings are being made or not, since the costs have been so variable, both that overall savings have been made:

Interviewer: Since this has been sorted out, do you think that you are paying more or less electric?

"Maybe just slightly less?"

"It would be less…its weather dependent because of you know, relying on the solar panel…obviously they work more efficiently in sunny conditions…. So where are we up to? The system is definitely more cost-effective, we have no more oil or gas to pay for, just slightly more electric".

As will become clear in the next section, this is, in fact, the most accurate assessment of "where the Green Street families are up to" in their new homes.

5.7. Actual energy consumption

Complete data from SMART electricity meters were available for 50 consecutive weeks, for 4 of the Green Street households. Data from the fifth meter was not transmitted reliably, a problem which

persisted even after the meter was replaced. Regrettably, this was the home that had experienced the greatest teething troubles with all aspects of their home, including sewerage, flooding, and drains.

Consumption data are expressed in kWh's at fortnightly intervals for each of the 4 homes that could be monitored. Figure 5.7. provides details. It compares the 4 households with each other, and with a control group of 50 other SMART meter households that were involved in the same SMART Trial as Green Street residents; these other households resided in normal gas- or oil-fired centrally heated homes, and all shared similar background and demographic characteristics as the Green Street Project families. Table 5.7. also provides details of the average consumption of the 5 families in the Green Street Project across 50 weeks, compared with a similar cohort of 50 SMART meter customers who are using the same meter but have a conventional heating system installed in their homes.

The figure and table illustrate that the average consumption for the control customers was 160 kWh per fortnight; this equates to 4160 kWh over a 12-month period. By contrast, the Green Street homes consumed almost 40% more electricity at 5694 kWh in the first year.

The Green Street families exhibited the same seasonal fluctuation in electricity use as other families on the SMART Meter Trial, although their spikes were considerably sharper. Furthermore, spiking occurred into summer, especially in 2 of the homes. Since the summer of 2012 was one of the colder on record in Northern Ireland, this could reflect the need for periodic top-ups of heating in an unseasonable summer (most homes in the region used central heating periodically during this time too). Taken overall, fortnightly patterns seem profoundly more variable for the Green Street Project residents than is the case for the other 50 customers taking part in the SMART Meter Trial. Some of this may be accounted for by the smoothing effect that averaging 50 customers produces. However, these do appear to be houses using electricity in a different way, as one would expect in homes where almost all heating and appliance use relied on electricity.

Fig 5.7. Fortnightly electricity consumption for the 4 families that had successful data transmission, compared with 50 control customers in conventional housing

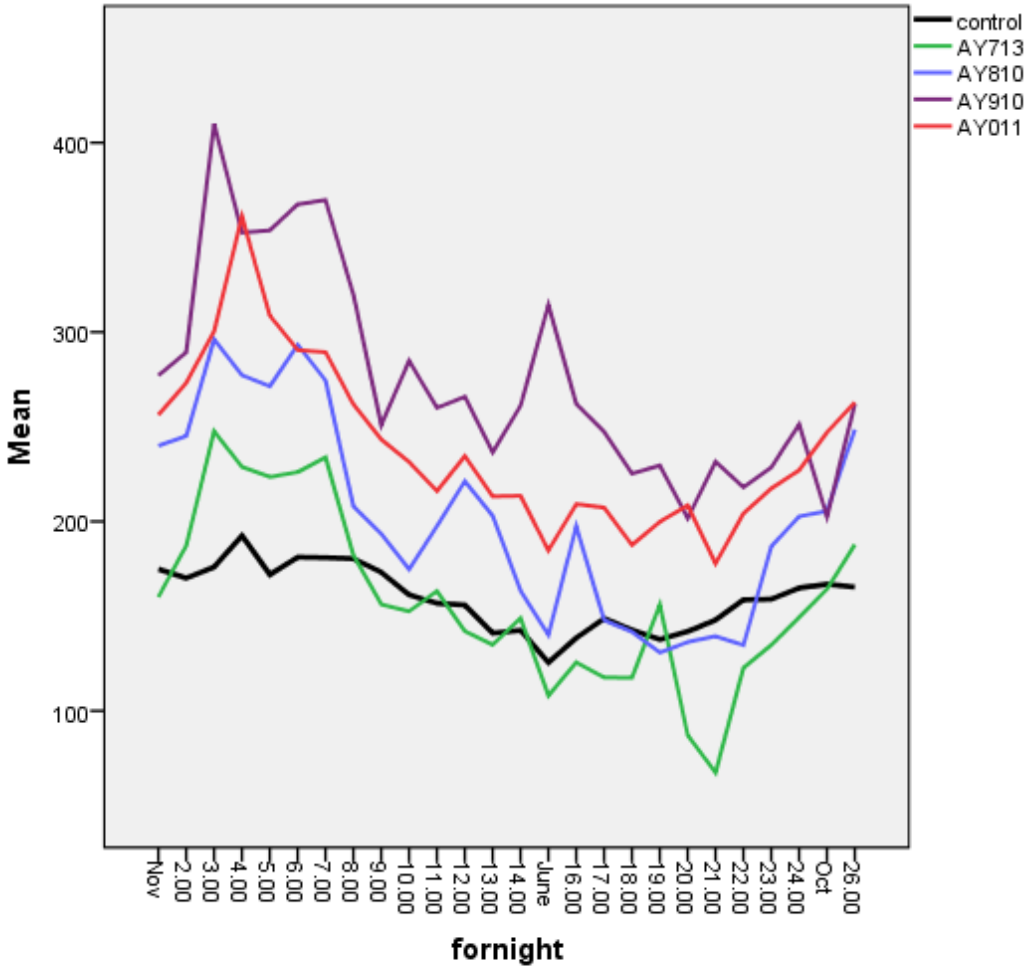


Table 5.7: Average fortnightly consumption for Green Street and control customers

Report

	Controls	AY713	AY810	AY910	AY011
Mean consumption per fortnight	**159.86**	**158.67**	**202.73**	**275.91**	**239.50**
Number of fortnights	**26**	26	26	26	26
Std. Deviation	**16.833**	46.025	52.762	56.021	44.175
Minimum consumption	**126**	67	131	202	178
Maximum	**192**	248	296	410	361

Table 5.7.2 provides details of comparative energy costs for the Green Street homes and the other Smart meter customers. Two of the Green Street homes had a gas fire installed (the gable end properties) and both residents agreed that they spent considerably less than £200 on gas during the first 12 months. Hence the aggregate sum spent on gas is £400. The average cost for all domestic energy needs in the Green Street homes was £955 per home in the first year.

By comparison, the smart meter control customers in conventional homes paid £623 for their electricity, and also paid either a gas bill (averaging £891), or an oil bill (averaging £1306). Gas-fired homes cost 37% more than Green Street homes for energy; oil-fired homes cost 51% more. This meant a saving for Green Street residents of £11 a week over gas-fired homes, and £19 a week over oil-fired homes.

In the first year, the Green Street homes cost 37% less for domestic energy than the average Northern Ireland gas-fired home, and cost almost £11 per week less to run; they cost 51% less than the average oil-fired home, costing £19 per week less to run.

Since more than three-quarters of Northern Ireland homes currently rely on oil for central heating, and many of these are unable to connect to the gas grid, the Green Street energy system offers an opportunity for significant savings on regional energy bills. Furthermore, these are savings that are being made in one of the coldest areas of the UK and Ireland, where heating is usually required for parts of every month in order to retain adequate and healthy indoor temperatures; Northern Ireland homes are heavy consumers of energy, for heating especially, so savings are reducing consumption that is at a very high baseline, both in terms of costs and carbon.

When considering the potential impact of low carbon housing for Northern Ireland, it is vital that emphasis is placed on comparing the Green Street homes with *all* housing in the region. However, a more stringent comparison can be made between Green Street homes and newer-built homes in the region. As indicated on Table 5.7.2, savings remain substantial, with Green Street homes costing 20% less than new-build gas-fired homes, and 34% less than new-build oil-fired homes.

Table 5.7.1 Smart meter controls and Green Street (GS) residents : energy consumption across 12 months (November 2011 to October 2012)

	Controls	GS1	GS2	GS3	GS4	GS Total	Notes
kWh consumed - electricity	4156	4125	5271	7174	6227	22797/4 = 5699	GS averaged 37% higher consumption than Controls
Annual cost *	£623	£619	£791	£1076	£934	£3420/4 = £855	
Gas heating all Newer homes	£891+ £575+	£100**	£100**	£100**	£100**	£400	
Oil heating all Newer homes	£1306+ £820	0	0	0	0	0	
Total energy cost All Newer homes	£1514 gas £1929 oil £1198 gas £1443 oil	£719	£891	£1176	£1034	£3820/4 = £955	**GS Average = £955** **37% cheaper than average gas-fired homes** **51% cheaper than average oil-fired homes** **20% cheaper than newer gas-fired homes** **34% cheaper than newer oil-fired homes**

*Set at 15p per kWh ** Only two of the 4 GS homes had gas fires; the total annual estimated cost for running these was considerably less than £200 per fire, according to the residents; to preserve anonymity, this £400 is spread evenly across all 4 households. +Sutherland Tables, average costs across October 2011 and October 2012 for homes with condensing boilers

We can also compare the Green Street costs in their first year with what they estimated they had spent the previous year in their "old" homes. Here, the average across the five families was £900 for heating and £530 for electricity (£1430 in total). At £955 their Green Street bill was 33% cheaper than what they had estimated they were paying in their "old" homes.

In terms of individual households, the family that was most content with their Green Street energy system, and were most convinced that they were saving a great deal compared with their previous home, were in fact the highest consumers in 22 of 26 fortnights. They consumed almost twice the electricity of the lowest –consuming household. (See line AY910 on the graph)

The household that had consumed least was the home which expressed the greatest disappointment with the thermal comfort of their home; this household believed that they were not saving over and above what they would have spent on oil. In fact, they consumed less than any of the other 3 households in 25 of 26 fortnights (see line AY713 on the graph). Furthermore, this household spent the same on electricity in a 52 week cycle as did the control households – even though the latter also had gas or oil bills to pay. Both averaged 159 kWh per fortnight; during half of the fortnights AY713 consumed less than the controls. It seems at least possible that the household is significantly under-consuming electricity and under-heating their home. Since they did not have a gas fire installed in Green Street, their total energy bill for the first year was £718 – almost a third less than what the other homes in Green Street were spending.

5.8. Longer term cost effectiveness

After the second winter in the Green Street homes had passed, UU researchers re-examined electricity consumption, along with degree day comparisons for winter months in 2011 and 2012. If households needed **x** kWh in winter months 2011 for **y** degree days, then that is **x/y** per degree day. All else being equal they would need **x/y** in the winter months of 2012 too. The decision to compare the two *winter* seasons was based on the knowledge that the families had moved into their homes in the summer of 2011; this was when they encountered difficulties and teething troubles with their new systems, and consequently consumed unexpectedly high amounts of electricity for a short period. Comparing their first full 12 months with their second 12 months would have been an unfair comparison, weighting results in favour of the second year. The first two winters provided a fairer comparison. Table 5.8 displays the degree day comparisons for 2011/12.

Table 5.8 Degree day and electricity consumption: comparison of 2011 and 2012 winter months:

Month	Date	Heating degree days	Month	Date	Heating degree days
Nov.	01/11/2011	251	Nov.	01/11/2012	260
Dec.	01/12/2011	333	Dec.	01/12/2012	313
Jan.	01/01/2012	284	Jan.	01/01/2013	316
Annual		**868**	**Annual**		**889**

The second winter in the Green Street homes should have demanded 2.4% more heating than the previous year based on higher Degree Day demand. Table 5.8.1 provides details of actual consumption for the first and second winters.

Table 5.8.1. Electricity consumption in 2 consecutive winters

	GS1	GS2	GS3	GS4	Total kWh
Actual Year 1 kWh usage in winter months	512	1090	2091	1824	5517
Actual Year 2 kWh usage in winter months	378	1152	1966	1665	5161
Expected Year 2 kWh based on 2.4% greater degree day demand	524	1116	2141	1868	5649
Difference between expected and actual (figures in black font denote a reduction in Year 2)	146kWh -28%	36kWh +3%	175 kWh -8%	203kWh -11%	488 kWh -9%

Whilst Green Street householders should have consumed *more* electricity in their second winter given that it was slightly colder than their first, only 1 family did so (the only home that contained young children). Overall, during these 3 winter months, the families consumed 9% less electricity than was expected based on their Year 1 baseline and the Year 2 degree day demand.

The UU researcher also carried out a follow up visit with the families in February 2013. During this visit, the Green Street householders seemed much more settled into their homes, some remarks included:

"The house has been fine, same as any other house in the winter really, sometimes you have to put the fire on for 40mins but it's really really warm after that"

"Sometimes you're running around in vest tops because it's so warm"

"In our old house we would have cardigans on during the day, now we always dress really lightly"

"Now we know how to work the house it works well"

All the households appeared warm and comfortable during the researchers visit. Difficulties that had been noted before such as problems with window insulation or flooding in back gardens had been resolved over time and currently do not pose a problem.

It is impossible to estimate the lifetime cost-effectiveness of the Green Street homes, since these need to be measured (or at least modelled) on a life-cycle basis, taking into account the initial purchase price, operational costs, long-term maintenance, and the lifespan of the buildings themselves. Moreover, cost-effectiveness must take into account the extent to which both gas and oil prices are set to rise over the next decade, whilst there is at least some prospect for lower-cost electricity generation through renewables and nuclear generation (Boardman, 2012). However, the results are promising when these homes are compared with gas-fired homes, and immensely promising when compared with oil-fired homes.

5.9. Other benefits of the energy system

With a heavier reliance on electricity, the families had become more price aware, and several of them had switched electricity supplier as a consequence:

"We changed over. It was good. One of the other families did first, and then told us about it. So we followed."

"Yeah, we knew nothing about it."

"And then you checked the meter the other week and it had come down more, and we were able to save a wee bit now for the winter."

Another benefit (which the residents themselves discovered) was that their low carbon status entitled them to rates relief. But this was a difficult application process, for which there was no support, and not all the families applied for it:

"We went for the rates relief because again, we weren't getting enough information about it and we had to do it ourselves. There was a charge of £50 for it, which Habitat weren't happy about, they thought that we shouldn't have had to incur that charge. Then we got all the forms and told everybody in the row about it. You can get up to two years free, but only one went along with me and paid and got it, the rest of them never bothered. I thought it was very foolish of them. It will be interesting to see when their rates bill finally does come around. We have another year of being exempt, according to what the brochure said on the rate reliefs for low carbon output. It was just something we went ahead with ourselves and got, and we are happy enough that we did. "

There were not many young children in the 5 houses, but those that were seemed happier in Green Street than they had been in their previous home (even though their previous home was only a short distance away):

Interviewer: Do you miss anything about your old house, the type of heating?

"(laughs) No I hated that house. I even find that the children are a lot happier and settled here. They didn't like that house at all for some reason but since they have come here the two of them have been dead on. They go to bed and all properly, and they sleep well in their own rooms and stuff. They are more comfortable in this house, than what they were in the other house."

5.10. Changing relationships - from collaborators to neighbours.

The early sense of cooperation that was established during the building process persisted during the early months after moving in. For example, one of the residents negotiated a deal with a cable company and made sure that everyone else in the group was able to avail of the same offer. As he remarked:

"That to me is just the old fashioned and neighbourly thing to do, you know…. We have worked with our neighbours building a home, a friendship has grown, we know them"

The remark is noteworthy in that it illustrates the extent to which low carbon transitions through pocket neighbourhood developments of this kind can engender some of the more traditional partnerships and support networks that people living in the same street more often enjoyed in previous generations. A thoroughly modern house does not preclude traditional values of altruism and neighbourly cooperation, although it is difficult to disentangle the extent to which enhanced neighbourliness derived from a joint building program or from the resident's joint status as special low carbon home-owners.

At least some of the families hoped these relationships would last:

"If we work as well as we did on the building site, then it is going to be as good to work within the houses, the relationships that we have built. Even if there was a problem, we would sort it out very quickly instead of not being nice to each other or something, because we have got to know each other."

However, relationships between the 5 families weakened over time:

"Our relationship has died down a bit, it has now" "Well we don't live in each other's house. "No, we just say 'Hello" and "How are you?" We would have more chat with them than we would with a stranger. You know, like this side of the street, we would talk more with them than the other side of the street. No, we would probably just say hello to one neighbour down the street that we built with. But that's it, everybody else just keeps themselves."

"The cross cultural thing is there as well, some of the neighbours would be Eastern European, no English whatsoever, so that's difficult and a barrier in its self. Not that we are ignorant or dislike each other in any way, it's just hard to communicate."

More sensitive issues have also emerged:

"And then there was a noise problem next door and I didn't want to go in but I had to go in tell….., but quite a few times, you know… They won't put up with that around here. Anyway, it just calmed down."

The comment that "they won't put up with that around here" was reflected in the fact that the wider neighbourhood began to impinge more and more on the families. Privacy was initially a problem, as it is in many new-builds where fences and shrubbery might not be ideal at first:

"And especially this (points to back garden) because that was very open when we came but then we went and got, do you know the…."

"I got extra wood"

"To block the slots because the kids were running up and down and you were sitting here and they were looking in. It's only natural, they're going to do it…but from that two of the other families did the same. It just makes it that bit more private."

For two of the families, the wider neighbourhood was especially salient. They had a particular interest in living on or near Green Street because they considered it home. For one of these, the relocation they made was from a considerably more middle-class area. However, they had lived there years before, and wanted to return:

"The area is much, much better than we thought."

"Oh it is. I don't know if you know but we moved from [a very middle class suburb]."

"People used to say 'Where are you moving to?'. And we are all excited buying a house…'Green Street', we would say. 'What's taking you down there?' And I would have said 'Well, John and I are from this road'. And when we moved in, I would have said 'Well come down for a day and see what

it's like'. Now our window cleaner we know him from school from years ago and he lives up in Hillsborough, and he came down a few months ago. He was outside and said 'Is it this quiet all the time?' And I said 'Yeah, see what you hear now, this is it'. 'I wouldn't have believed it' he said 'if I hadn't of…', so I mean people judge it right away, 'Oh Green Street, peace wall', you know? And this is it all the time, you don't hear anything."

The same applied to one of the families with young children, for whom closeness to the children's maternal family was a significant advantage:

"It's close to my work, and a lot of the family live around here, so if we need any help with the kids, it's good that way".

However, for other families, events in Green Street became problematic within the first year. Some of this stemmed from crime:

"The car window has been smashed since we were here as well, just lots of things. Maybe if I had have known, I maybe would not have went for it."

as well as from sectarianism:

"It's more of a flag point here, where we live. And obviously we would get more stones and bottles still occasionally… especially coming up to the silly season here."

Interviewer: Does that make things difficult for the kids?

Well it's more of a worry for me, they don't ."

"Children don't get out to play here"

"They would be oblivious to it you know, so you just have to wrap them up in cotton wool and grin and bear it ."

For the 2 families who were not from Northern Ireland originally, problems of acceptance became even more sensitive, leaving them feeling unwelcome and threatened by people in the wider neighbourhood:

"Emmm…well if you are asking about the house and the building, it's ok. You can learn to live and hope that it will not be too cold (laughs). We have more concerns about the area and the neighbours…it overshadows, you know? The house is not the issue, more the location."

This was echoed by the other family who were not from Northern Ireland originally:

"Things are not so good anymore. It was ok to begin with, but then we started having problems with the neighbours and all, and now we might have to move out. It is sad, because it is quite a cool house and we did everything ourselves if you know what I mean. We were building it. And now we do not have to pay a lot for electricity and heating...everything has been great but it is just the area if you know what I mean."

Interviewer: All being well you would like to stay here and not have to move?

"Yes, but I think we will have to. We are looking for somewhere new. Although it will be nowhere like as good as this, but for our safety it is better to move. "

5.11. The Green Street composite

Looking at the experiences of all of the families, from the time that they first committed to the project through to the end of their first year, it transpired that the family which had built up the least hopes, and taken the longest time to commit to the project because it was not a high priority for them to do so at the time, were also the family that were happiest with their home a year later. They themselves thought that this was because they had not built up any high expectations, having been busy raising a new baby and a young child at the time of the build:

"We didn't know what to expect so we weren't disappointed, everything was just new."

A second family had readily embraced their new home and the challenges of a new energy system, carrying with them the immense initial optimism and enthusiasm they had started out with. Both of these families were originally from the Green Street area, and both reflected on the extent to which they felt more rooted in their homes – the new home felt like part of their identity. These families had become ambassadors for the homes:

"I call it an eco friendly house anyway…and the water is heated by, you know, solar panels. And they say '*O they heat your house?'. A*nd I say 'no they don't heat your house', so they reply '*then you must have under floor heating'. "N*o we don't have under floor heating". '*Then what heats the house?'* And then you have to go into all this, you know…and a fella from the gas company stopped me yesterday in Connswater (*a shopping centre*). He asked 'what type of heating do you have?' and he had this big camera (laughs) and he said 'Don't be worrying I'm not filming people'…and I said 'No I'm used to the camera' (laughs). And then he asked "What kind of heating?' and I said 'None'. 'H*ave you under floor heating?'* 'No', 'Y*ou have oil or gas then?'.* I said 'We have neither', and I started to explain to him, and he was fascinated.

The same level of satisfaction and a feeling of being home did not transpire for the two families who were not from Northern Ireland, and in ways that were not anticipated, but perhaps could have been.

Chapter 6

Interpreting the results

> "Together, the dwelling and its occupants form an integrated system in which people live their lives and, in the process, use energy and emit carbon. The relationship between a dwelling and its occupants is highly complex and varies over time. Indeed, it has been suggested that home is much more than simply bricks and mortar. It is imbued with meanings of attachment and rootedness, where people feel a sense of control over space and can withdraw from the rigours of the outside world (Seamon, 1979; Cresswell, 2004). Arguably, how people use a property relates as much to their own set of personal circumstances as to the appliances and systems that are available within it. Producing successful sustainable housing is therefore as much about understanding this relationship and supporting household needs as improving the fabric performance." (Bell et al., 2010, p. 40)

6.1. Green Street and similar low carbon developments

When compared with the experiences of similar families who have moved into low carbon homes of this kind, the 5 Green Street Project residents are not at all unusual. Their experiences have been very similar to those documented for similar residents in small pioneer projects of this kind. The Elm Tree Mews project in England is perhaps most similar to Green Street, having 5 of 6 homes occupied and with post-occupancy evaluation a year after moving in. All but one of the homes had considerable teething problems, but most of these were resolved during the first year.

Other evaluations of similar projects have highlighted that success most often relies upon a variety of elements being put in place before the project commences. First, careful alignment between what is planned, and what community resources and capacity can manage, was found to be essential. This appears to have been adhered to in an exemplary fashion in the case of the Green Street build, with help always at hand from the designer, building teams, Habitat For Humanity NI, volunteers, and neighbours. These sorts of self-construction and education initiatives are thought to provide the best means to foster awareness, responsibility, and capacity (Kyser, 2012), and this too seems to have

come to fruition in the Green Street Project. A comparison with the Elm Tree Mews Project, which was not self-build, is helpful here:

"Studies such as the evaluation of the Elms Tree Mews development in Suffolk indicated significant problems experienced by residents when engaging with new technologies causing considerable confusion among residents. Controlling the supply of hot water was a particular area of difficulty. The fact that residents did not understand the new systems meant that they lacked the confidence to make changes that best suited their own needs." (Combe et al., 2011).

Whilst Green Street residents did not understand their new energy systems either at the time they moved in, their experience in having built the houses engendered a confidence to learn how adjustments could be made, even though finding successful solutions sometimes took them many months.

What is evident from the post-occupancy evaluations in Green Street is that the timing of information provided to people is crucial. It is of limited utility in the months before families move into a low carbon home, which is when it was first provided. It remains of limited utility until such time as the default settings of the energy system no longer fulfill their requirements. Households are best engaged at the point when they seek advice. At that point, they are also better empowered by information that is specific to what adjustments they wish to make rather than solutions being embedded in generic manuals or guides. This is particularly so in cases where households have not specifically chosen to live in a low carbon home, and where relocation is embedded in a wide range of other challenges such as purchasing a first home and participating in its construction.

It is without doubt that most or all of the advice and guidance that the Green Street residents needed before relocating had in fact been relayed to them before they moved in (the researchers involved in this evaluation heard much of it themselves). However, it was information that residents perceived as being piled atop a whole range of other information they were coping with and trying to assimilate at the same time ("whole reams of stuff" being the description of one of the residents). The information needed its own space and timing, which could have avoided some of the early teething troubles. Some low carbon evaluations have also concluded that incremental implementation, which offers new residents the opportunities to adjust to new energy systems in a phased manner, work best. This approach usually deals with managing temperatures first, followed by hot water, and finally appliance control, which ensures that residents do not feel overwhelmed

at the start of their residency in a new home. Given their confidence and construction experiences, It is doubtful that any of the Green Street residents needed this. However, little will substitute for a series of consistent, clear messages, delivered in person where feasible, and offered only at the point when management of the energy system begins to create difficulties for residents. Talks before moving in, and manuals thereafter have much less efficacy.

Comparison with the Elm Tree Mews development in Suffolk, England suggests that the Green Street residents may have been more fortunate than others in terms of what they contended with:

"For the householder, the complex nature of the heating and hot water systems meant that they were faced with a bewildering array of controls including a main heating controller, hot water controller, immersion timer (including the automatic pasteurisation cycle), room thermostats and solar controller. The potential for confusion was considered by the design team, who provided a plain-English guide to the controls for incorporation into the resident's handbook. There was also an expectation on the part of the designers that some controls (the solar controller in particular) would need little or no adjustment once set up at commissioning and on occupation, thus simplifying the control array. However, whatever the design expectations and provision of information, it was clear that the communication of this information to the residents was not effective....Crucially, the heating and hot water system was complex enough without seemingly simple technology, such as a thermostat, being difficult to understand and adjust. It also raises a more fundamental question about why such controls are used generally in the construction industry when they do not provide residents with information in a way that enables them to exercise effective control over their heating system." (Combe et al., 2011)

Many similar reports on low carbon or passive housing describe systems which are said to be perfectly "calibrated" before residents move in, with the hope that no one will ever feel the need to try an adjustment. This is, clearly, an unworkable management system given the very different thermal preferences that we observed in the 5 Green Street homes. Ensuring that residents fully understand their systems and feel able to control them on their own is essential:

"'Home' is the site where people can feel in control of their space (Seamon, 1979; Cresswell, 2004) and when this control is disrupted it is likely to have an impact on how rooted and content they feel with the property. Having the knowledge and confidence to make use of the dwelling in

terms of heating, energy and ventilation affects your control over the internal comfort of the dwellings." (Bell et al., 2010).

The responses of the Green Street Project residents at post-occupancy evaluation consistently made clear that being in control was important to their sense of satisfaction with the home, and their more general well-being. For one of the families in particular, they were still far from feeling any real sense of control since they still had significant difficulties with plumbing and flooding. These are issues which have clouded any real satisfaction that they might have reasonably expected from their new home. There seem to be somewhat blurred edges around responsibility for these homes, stemming perhaps from their being part-owned by the families and part-owned by a Housing Association. Ensuring that responsibility is clarified seems vital, since these faults are creating unreasonable burdens particularly in terms of the household's ability to carry out their most basic routines of laundering and dishwashing.

6.2. Managing expectations

If low carbon housing is to offer low income households homes that are both affordable and desirable, the range of potential energy savings need to be made explicit, since these have varied widely across the 5 homes. It was not always the smallest families which used the least energy, nor those with young children who used most (as is commonly found in UK households). When highlighting energy savings from low carbon living, it will become increasingly important to provide potential customers with an understanding of this wide range of variability, in which little can be predicted with certainty. Nevertheless, when compared with consumption per square metre in similar homes elsewhere in the UK, the Green Street homes used considerably less than, for example, the Elm Tree homes in Suffolk. Per square metre, the Green Street homes consumed between 42kWh and 74 kWh in their first year. This compared favourably with the Elm Tree low carbon homes which ranged from 68kWh to 92 kWh/sq metre (Combe et al., 2011)

One of the Green Street residents had researched passivhaus concepts whilst trying to resolve early problems. The Green Street homes were not passive houses, but rather low-carbon homes. If this was in fact a misunderstanding of how Green Street homes were intended to perform, it could have contributed to this particular family's disappointment with their home. Here too, appropriate

information, given at the point when solutions were being sought by the resident, would have been timely.

6.3. Saving money

Four out of 5 families believed that the Green Street homes were a cost effective alternative to their previous homes. Once problems of management and equipment settings had been taken care of, the families felt that they were spending a bit more on electricity than they had in their previous homes, but this was offset by a very limited expenditure on heating fuels such as gas or oil. Whilst the families themselves seldom remarked on their savings, and seemed to view them as "modest", they were in fact substantial when compared with gas-fired central heating systems. The families themselves realized that it was difficult for them to assess how much they were saving because of the great seasonal variability in their energy bill.

6.4. SMART meters and low carbon transitions

All 5 families noted the usefulness of their SMART electricity meter, and remarked on how much they relied on the In-House Display; this allowed them to monitor the home's energy use, and understand more about how the new energy system was functioning. Moreover, the SMART meters were an integral part of finding solutions to teething troubles with heating which emerged at the onset of winter; there were multiple opportunities to monitor and manage the new energy system which collectively meant that problems were caught very early on, rather than being discovered only when the first quarterly bill arrived. This is an important finding. Although SMART meters are not yet widely available in Northern Ireland, Pay As You Go (Keypad) meters with an inhouse display (the Freedom Unit) have been for a few years; they offer cheaper electricity rates for customers and are widely used by customers from all income groups. These Pay as You Go meters should be mandatory in future low carbon developments in Northern Ireland, since they have proved central to the identification and resolution of early management problems in Green Street.

6.5. Temperatures: Thermal comfort and hot water heating

Temperatures in the homes were not uniform or perfect, although bathrooms performed at an excellent level in terms of thermal comfort. Evaluation of the ASHRAE Scale indicated that the families had found the homes cool in winter, although a modest introduction of heat through convector heaters quickly helped to resolve this. Other studies indicate that residents are much more prepared to tolerate slightly cool conditions if they feel they have control over these, a process known as *interactive adaptivity* (Stevenson, 2012). In the case of these particular families, it is difficult to ascertain at this early stage whether thermal comfort will prove less of a concern next winter (because they feel more able to attain it), or whether residents will begin to focus more on thermal comfort now that most other teething troubles have been resolved.

Overall, both home and water temperatures were weather dependent, but the families felt that they had adjusted well. A mixer tap system on all sinks and baths would be an excellent option for future homes, if not an automatic thermostat control to prevent water being at unsafe temperatures, especially for children.

6.6. The future

Sustained communication between the families and the designer, especially as they enter their second winter remains essential. Given that levels of thermal comfort have not yet approximated a happy medium for many of the residents, and given too that they feel they have ironed out most of their earlier difficulties in adjustment, it is likely that their thermal comfort may begin to assume greater priority. So far, it is the management of temperatures in winter that has emerged as the most enduring challenge in their first year; satisfactory resolution of this in their second year would be ideal, especially in view of the extent to which the families have already adapted to their new systems. Given that they were not fully aware of what this would entail when they "bought into" (quite literally) the Green Street Project, they have shown resourcefulness and a determination to understand their systems; continued guidance and support will allow them to complete their low carbon transition.

The experiences of Green Street residents could be important in the longer run; at least one family may be in a position to become a realistic ambassador for low income/ low carbon living. It is commonly agreed that real-life examples, based on people who are much like everyone else offer the most convincing and persuasive information for people contemplating a transition to low carbon living:

"Consumers need to see real, day-to-day examples of how sustainability is integrated into real homes and real lives. Media needs these real life examples as a basis for articles and programmes. Exemplars do not do this. Exemplars are, in the main, the prototypes, the flagships, the demonstration projects – in other words, the future, not the present. They are the housing equivalent of the concept car. Consumers are more persuaded by real homes and real lives" (Boardman, 2012).

Studies suggest that developments like the Green Street pocket neighbourhood are seen by neighbours as being "modern", "attractive", "high tech", "fashionable" and "good value". In the context of the Green Street Project, trusted community organisations such as Habitat For Humanity NI can also spread knowledge of best practices for affordable and low carbon housing, and there is no doubt that their role in smoothing the transition to new homes was vital for all of these families. However, they played a much more limited role in partnering them through a low carbon transition (which is not a common role for HFHNI), and future HFHNI schemes of this kind could be more proactive in that regard. More importantly, the extent to which the traditional Habitat for Humanity model, in which a series of volunteers (new groups of inexperienced helpers leaving and joining on a weekly or daily basis) are given a role in constructing a low carbon/high-specification building that requires expert knowledge and precision, remains an open question. The experiences of almost all of the Green Street families indicate flaws in the build quality, some of which may well have affected the functionality of their energy system, and all of which impinged on their ability to adapt.

The fact that this system is not suited to retrofitting existing homes means that it will always involve relocation. This makes all the more essential a protocol for enhanced client support in the form of:

- Preparation for the new system –for new developments, this could include a visit by families to the Green Street homes, to learn from their experiences (should families be willing to become ambassadors for the system).
- A broader introduction to the principles and value of low carbon living e.g. its status as a flagship solution to climate change, being a leader in the unfolding of a modern and progressive lifestyle. None of the Green Street residents expressed any sense of how important a role they were playing in informing low carbon projects for the future; this

may be a result of their natural modesty but was probably also because this had never been articulated fully.

- A realistic framework of what to expect from the system e.g. teething troubles, options for solving shortcomings, energy savings that will accrue over a decade of living in the home (these are substantial, and are vital to providing clients with a "coping cushion" on the occasions when they encounter problems or disappointments with the system) This should include:

- Examples of savings that can be made in TTF homes, compared with costs associated with similar homes run on gas or oil in Northern Ireland, using Green Street findings as the baseline for comparison.

- A comprehensive and easy to use manual that is introduced to the families in the preparatory phase, and with which they become fully familiar before moving in

- A week-long on-site support plan at the point of moving in

6.7. The families

The 5 Green Street families experienced much more than a relocation to a new home. They helped build their new homes, waited more than six months longer to move in than they had been promised, experienced significant teething troubles in managing a largely untrialled energy system, and remained, throughout, willing to find solutions and accentuate the positive. Even before they relocated, they were apprehensive of managing the new energy system, and experienced stress just thinking about it. That they adapted so readily, and were as willing to engage in finding early solutions to problems is testimony to the determination and focus that they displayed from the start of the Green Street Project when they first decided to take part.

What has not been transcribed, because it was never mentioned in the recordings, was that the families all experienced significant and life-changing events during their first year in Green Street. These concerned the health and wellbeing of their closest family members, threats to personal relationships they held dear, and threats to their personal safety. Issues related to ventilation and adding extra heat paled into insignificance at times, although they could certainly have managed without these additional stressors. The impact of unexpected life events will not be unusual among

households participating in Trials of this nature, but here these were laid over the stressors associated with:

- contributing to the building of their new home
- mastering a range of new building skills
- raising the finance for a new home, in most cases for the first time
- being part of a collective development and managing the dynamics associated with this during both the waxing and the waning of these relationships
- living in the spotlight of a pioneering new development that occasioned a range of monitoring equipment installed in their new homes, television crews, radio interviews, photo sessions, and the repeated attention of two University research teams.

There were surely quieter and more realistic platforms on which to examine the experiences of families making a low carbon transition.

Chapter 7
Conclusions

"Even with the growth of web-based information systems, significant behavioural change results primarily from more trusted role models than Government can offer e.g. family, friends, and community leaders. The implication is that similar principles of technological innovation need to be applied, with Government supporting and financing social innovation but not undertaking this innovation itself e.g. by financing social entrepreneurs and community projects. One way of giving greater energy efficiency more status would come from the recognition that the properties are more comfortable, provide healthy living conditions and are future-friendly. The cold, mould, condensation, and sick-building syndrome could all become things of the past, residing in the memories of older generations." (Boardman, 2012).

Forrest and Wiek (2014) note that people around the world are initiating transitions toward sustainability, with a notable segment of these initiatives taking pace in "small, place-based communities", or pocket neighbourhoods. Other, much larger initiatives include transition towns and low-carbon communities. Each initiative, they argue, presents learning opportunities to build robust transitions that may contribute to progress toward a sustainable society in general. However, they also note that little empirical research has been conducted on "how the transition context and process lead to particular outcomes". The present report comprises an example of empirical research in that domain, providing an in-depth and personalized account of one pocket neighbourhood, followed from just before households moved in, for a period of 2 successive winters.

At a theoretical level, this intervention is embedded in the concept of *transition: "* Transition is built around the idea of developing community-led responses to the twin challenges of peak oil and climate change… The term 'Transition' is often simply characterized as a shift away from 'unviable way of living' towards a future with 'lower energy' but 'happier, fairer and stronger communities'.. In practice, transitioning towards more localised and resilient communities is the overarching

objective of the movement (Felicetti, 2014). During transitions, change towards sustainable practices is construed as an entanglement of both social and technical-structural elements across time (Iveroth & Bengtsson, 2014). In this process, the architectural and design structures of a home, and the information technology that provides residents with feedback are the enablers; the residents and their activities are the tipping-point factors that ultimately determine the success of changing individuals' behaviour towards a more sustainable direction. Each need each other in order for sustainable energy practices to emerge. The accounts provided here offer a wide range of examples of how these "entanglements" can unfold, and offer useful lessons for the future.

The Zero Carbon Hub has proposed that compliance with Building Regulations should always be based on the performance of the finished and occupied buildings. This ensures that construction delivers the expected standard and not some theoretical design. Slippage can occur as a result of construction faults, but they can also occur because of users who wish to determine how they wish to ventilate and heat their homes, the comfort levels they adopt, and the degree of understanding and commitment that they bring to the task of managing a new system.

It is clear from the Green Street homes that both forms of slippage emerged in the first year, but that many of these were resolved over time. Boardman (2012) believes that studies which generate results for finished and occupied buildings will be transformational in the near future since they will reveal the gaps between design and practice that need to be filled in any pioneering new approaches to building homes.

The present study joins a small but growing portfolio of projects which concentrate on "finished and occupied" buildings; furthermore, it has been able to monitor occupation over an unusually long period of time; this has allowed residents to both experience problems, and – by and large - find solutions for them. In this context, the data do not deceive. Green Street families were paying 37% less for their domestic energy than were households using gas heating systems, and 51% less than households using oil. By the time they experienced their second winter, with the initial problems related to hot water resolved, winter costs had been further reduced by an average of 9%.

In summary, the project represents Northern Ireland's first attempt to introduce such a high-specification low carbon technology (often construed as the privilege and preserve of higher income families) into homes that are affordable for all. How much has been learned?

In terms of Zero Carbon Hub's 10 rules for promoting low carbon homes, this Trial fulfilled almost all of them, with the exception of the first:

1. Clarity of vision. Consumers need to see the big picture and a concept which they can understand. In the case of the Green Street pocket neighbourhood, it could reasonably be argued that even the families were not sure of the vision before they purchased their homes, some of them being unaware that they were buying into a low carbon development.
2. Target influencers. The engagement with media, politicians, and stakeholders associated with HFHNI was extensive, although this was more evident during the build and at the launch than it was thereafter. This could, however, be construed as a positive feature, since the families have largely been left to normality in their first months of low carbon living. Whether the time is now right for re-engagement with influencers, given the positive results generated from this evaluation, is something that will now need to be considered.
3. Position new homes as normal. New homes have the opportunity to be the better choice – not a choice that is more expensive or more risky than the existing homes market. This was fully accomplished with the Green Street development. The homes cost no more than the other 180 homes in the street, and were of similar size and appearance.
4. Integrate sustainable homes across a development. Avoid segregating low and zero carbon homes on a development, which risks creating a perception that these properties (and those who live in them) are somehow different to mainstream. Several of the residents had lived in the street or near it before their move. The families themselves were not "green" in nature, but moved into low carbon homes with very little knowledge of eco-energy.
5. Avoid radical changes. Consumers respond more favourably to small incremental changes. The residents could probably have benefited from more support in the first month or two in their new homes, but proved fully capable of managing radical change.
6. Build all aspects of a more saleable product. The product must be an economically sound option for supply chain partnerships. The homes were well under the average price of a Northern Ireland home, and cost considerably less to run.

7. Simplify financing. The relationship with Clanmil Housing Association meant that many of the families were enabled to purchase their first home, but more attention needed to be paid to clarifying the roles and responsibilities of Housing Association and new part-owner.
8. Market these homes, instead of simply trying to sell them. The evaluation illustrates a wide variety of levels on which marketing will be feasible; these homes are comfortable, energy efficient, and cost significantly less to run than the average Northern Ireland home. The fact that the technical specifications of their design allow for flexibility in size, layout, and appearance are other important marketing features.
9. Identify a trusted consumer advisory system. This would provide unbiased and easy to access information. There is potential for endorsement by trusted energy efficiency agencies in Northern Ireland, Housing Associations, and the government departments which helped fund the project (DSDNI) and the evaluation (DETI).
10. Provide messages that resonate with the consumer. Consumers respond to realistic examples. Focus on marketing examples that seem "like us", rather than flagship exemplar projects which are seen as unattainable. To the extent that these homes have nurtured ambassadors, they have considerable potential in this context.

Taken as a whole, the results indicate that there is no obvious impediment to asking modest-income families to pioneer new energy systems, even though they have no prior experience of them, and are not even originally motivated to become pioneers in this regard. Green Street residents rose to the occasion across the board. They were tolerant, observant, always willing to be involved in finding solutions, and ultimately they were pragmatic in terms of what was achieved after their first year. All 5 families merit considerable respect for their demeanor and fortitude.

If such schemes are rolled out in the future, much larger samples will be needed to obtain a broader understanding of how low carbon homes function in the real world. These 5 families were very different in composition, lifestyle, attachment to the Green Street neighbourhood, and in their energy needs. Low carbon homes need to be able to fit around every type of household's needs; the Green Street experience has suggested that this is possible in the main, although with perhaps more attention to individual details.

As well as attention to individual detail, a build quality is required that is not affected by a changing team of volunteers working onsite every week. There were significant building flaws which would

be problematic in any house but are even more worrying when evident in low carbon homes that should be built to a very tight specification.

If the efforts of making a low carbon transition are to seem worthwhile to families that decide to make this choice, the homes need to be located in areas or neighbourhoods that are desirable and have meaning for the residents. It is probably not a coincidence that the 2 families who have felt most satisfied with their new homes are the families who came from the area and very much wanted to live there. Low carbon homes built in neighbourhoods where residents can relocate down the street or across the road (which one of our families did indeed do) mean that dislocation is minimized. Adjustments then have to do with managing a new energy system and a new space, rather than having to manage many other aspects of relocation such as new schools, transport arrangements, and neighbours.

It is also imperative that low carbon housing development are built in more neutral areas. The decision to locate these low carbon homes in a politically sensitive area close to a peace wall fitted aptly into the Habitat For Humanity NI model of bringing people together from different backgrounds. They rely on families who are prepared to come together to work alongside each other and build good relationships, often after long periods of hostility and conflict. In the case of Green Street, it seems that parts of the wider neighbourhood had difficulty in accepting some of the families who came forward to participate in the Habitat For Humanity spirit.

Even in the most benign locations, the challenges of a new home with an innovative energy system are likely to be formidable. There will always be unexpected life events that generate additional stressors – family members become ill, people lose their jobs, and children come home with unexpected problems. These events are in themselves sufficient to confound pure assessments of how people adjust to a low carbon home; feeling unwelcome and threatened in the neighbourhood is a burden of a different order, and one which has made it difficult to obtain a rounded view of the potential of these homes.

Sustaining a pocket neighbourhood of low carbon living in an environment like Green Street – which was already a combination of two isolated pockets separated by a peace wall – was a major ambition, especially given the mix of families that participated in the project. In the larger scheme

of things, the challenges that threatened the integrity of this low carbon pocket have relatively little to do with their management of a low carbon transition.

But despite these difficulties for interpreting the results, the SMART meter data do not lie. Families were paying a quarter less for their domestic energy than the average family in a conventional home with gas central heating, and more than 50% less than would have been paid in a home heated with oil.

The families involved in this natural experiment were ordinary people, which is important for the potential of their pioneering efforts to proliferate. Rettie and colleagues (2014) note that consumers are more likely to adopt behaviours and products that they think are normal, but they go on to note that what is regarded as normal changes over time. “New activities and products that are initially seen as different, and as outside normal behaviour, can eventually become mainstream and accepted as normal, in a process of social normalisation”. They critique the approaches of companies and policy makers, who tend to position green initiatives as targeting a niche market; they argue that this inhibits social normalisation and mainstream adoption. Green marketing can potentially play an important role in the social normalisation of green practices and products, but more so by portraying these as normal and everyday instead of emphasizing their uniqueness. The narratives of these 5 Green Street families are exemplars of such normalisation.

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